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SOCIETY FOR THE
PROMOTION OF ENGINEERING EDUCATION

REPORT OF THE INVESTIGATION OF ENGINEERING EDUCATION
1923-1929

ACCOMPANIED BY A SUPPLEMENTAL
REPORT ON TECHNICAL INSTITUTES
1928-1929

IN TWO VOLUMES

VOL. I

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FOREWORD

The accompanying report marks the culmination of a comprehensive study directed to the improvement of Engineering Education proposed in 1922 and undertaken in 1923 by the Society for the Promotion of Engineering Education.

The enterprise was inaugurated as a cooperative undertaking in which the schools should actively participate. The work was planned and conducted by a staff under the direction of a Board of Investigation and Coordination. The schools supplied data in connection with the extended fact-finding features of the investigation and contributed through special and local committees in the study of particular problems and in other ways. Engineering societies, industry, governmental agencies and individuals cooperated.

The assemblage of facts and data pertaining to the field of engineering education affords a definite idea of what is now being done. It presents to those who are familiar only with the particular institutions or fields of work in which they are engaged a general view; the present study integrates the whole field in a way to afford insight into needed developments as well as an appraisal of the present situation. It presents the conditions within the schools and much information regarding the entering student, the alumnus, the attitude of practicing engineers, teachers and industrial managers. It presents a basis for consideration of problems within the engineering school, both undergraduate and graduate, and it shows in illuminating perspective its relations to other fields—the preparatory school, the training courses for graduates in industry, the technical institute, the engineering profession, and the economic phases of modern life.

Both the Director of the Investigation and the Associate Director visited most of the engineering schools in this country for information and counsel, thus gaining the intimate knowledge of conditions essential to an evaluation and interpretation of information gathered by other means.

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The Director made two trips to European countries to visit the engineering schools. The result of these visits form the basis of a perspective comparison of engineering education at home and abroad.

An important outcome of the general investigation has been the establishing by the Society in 1927 of summer schools for engineering teachers. These schools have brought together each year, for periods of several weeks, nearly a hundred engineering teachers for consideration of better methods of teaching as well as for the discussion of the subject matter and the state of the art in their respective fields.

The findings and preliminary reports of the investigation have been made available immediately through continuous publication in the Society's monthly *Journal of Engineering Education,* and in some twenty pamphlet reprints issued as Bulletins and Reports.

These are now brought together, revised and supplemented in the present complete Report.

The contributions by the Board and by the Staff present summaries, comment, conclusions and recommendations. Director Wickenden presents in a general report the views of one whose prior career as teacher in engineering schools and as director of educational work in industry, qualifies him to appreciate the problems involved. Professor Hammond, Associate Director, has had charge of the immediate relations with the engineering schools during the fact-finding period. He has also organized and directed the conduct of the Summer Schools upon which he has prepared a special report.

The initial funds for the investigation were provided by a grant from the Carnegie Corporation. These were supplemented by contributions from engineering societies, from industries and from individuals.

A supplemental study of Technical Institutes reveals the status of a neglected field closely related to the collegiate engineering schools and indicates the need of a comprehensive national scheme which will include all branches of technical education. The report of this study is published in this report for the first time in complete form.

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REPORT OF THE CHAIRMAN OF BOARD OF INVESTIGATION AND COORDINATION

CHAS. F. SCOTT

I. Inception of the Project

This movement to better engineering education arose from a belief that the Engineering Schools should take concerted action in studying their new and common problems. It was seen that Engineering is continually assuming larger importance in modern affairs and that the Engineer of the future "will be called upon to take a more important part in great enterprises . . . , in organization and leadership as well as technical service in the solution of new problems (industrial, economic, governmental and social) which the engineering applications of science have produced."

It was also realized that there had been a relatively static condition in engineering education for a decade, following a half century of rapid expansion in the number of schools—the increase was from less than half a dozen to well over a hundred—with corresponding increase in attendance and a notable expansion in the scope of the curricula. This relatively stabilized condition occurred while other groups of schools, some in fields related to engineering, were going through a period of rapid expansion. Medical education, also, following radical change in educational policy, enjoyed enlarged public recognition and financial support. Among the influential schools of law there was pronounced advance in educational standards.

Engineering schools were undergoing no essential modifications, possibly because of the sound status already attained, although scientific research was productive and the growth of industry was unparalleled.

In the World War the achievements of science and engineering and industry were most impressive. Engineers, individually and collectively, had notably demonstrated their capability in technical and administrative service. Then came

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the after-war reaction. The validity of the older order was doubted. Educational systems in general were questioned as to objectives, methods and results.

The situation in engineering education was presented to the Society in several editorials in the *Journal of Engineering Education* followed by the Presidential address * at the June Convention in 1922. A Development Committee was then appointed to formulate an answer to the question "What can the Society do in a comprehensive way to develop, broaden and enrich engineering education?" The committee recommended that the Society undertake a comprehensive survey directed by a Board, which should have authority to appoint a Director of Investigation and a staff, and to secure funds for carrying out a comprehensive program. Later the members of the Committee were appointed members of the Board of Investigation and Coordination. The report of the Development Committee was then sent to the heads of Engineering Schools and received constructive comment. A year later funds were secured and a Director appointed.

Negotiations for Securing Funds

(a) The Carnegie Grant for 3-year Period

A former project of the Society, initiated by Professor D. C. Jackson when President of the Society in 1907, resulted in a report by Dr. C. R. Mann, entitled a "Study of Engineering Education" published in 1918.† This study was made under the auspices of the Carnegie Foundation for the Advancement of Teaching. As this report indicated that a further investigation was desirable, it was fitting that the new project should be presented to Dr. Pritchett, President of the Foundation, who had personally taken an active interest in the prior study and who was acting temporarily as President of the Carnegie Corporation. He received the new project cordially. He suggested some modifications in the program and proposed that we consult with other Foundations regarding their sharing in support of the project. The several foundations gave our proposal thorough and discriminating consideration. An objection to our plan of investigation of engineering education by engineering educators was raised on the ground that it might result in nothing more than a mere ''reconciliation of views.'' The President of the General Education Board suggested that a study of education in European countries might be helpful in engineering as it had been in other fields; a suggestion which resulted in a most fruitful part of our project. Representatives of the several foundations agreed that the engineering project merited support which could appropriately be continued by the sponsors of the earlier study, particularly as Dr. Pritchett had been president of one of the leading engineering schools. Conferences with him resulted in an outline for the proposed study which he approved in a letter, May 29, 1923, which concluded with these words ''and I shall heartily recommend that the Carnegie Corporation participate in its support.'' Favorable action was taken in October of that year and a grant of funds was made covering the first three years of a proposed five-year program.

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* By Chas. F. Scott.

† Bulletin No. 11 of the Carnegie Foundation for the Advancement of Teaching.

A condition of the earlier study was that the investigator should be chosen and the report approved and issued by the Foundation; the committee of educators and engineers served merely as consultants and advisors. In the new project, however, full authority was vested in the Society for the Promotion of Engineering Education, including selection of staff, conduct of the enterprise, form and contents of reports. Presumably the fact that this Society had been in existence for thirty years and had accustomed engineering educators to work together on their common problems gave assurance that engineers whose province it is to make investigations and formulate sound conclusions might be entrusted to study their own problems. This method characterizes this enterprise as a radical departure from the plan upon which educational investigations and surveys had been commonly conducted in the past and the results show that an analysis of a field of education with constructive aims may be conducted by the schools and individuals directly concerned.

The meeting of the Carnegie Corporation, at which the grant of our funds was made, was presided over for the first time by its new President, Dr. F. P. Keppel, and our subsequent dealings have been with him. He has been cordially sympathetic and constructively helpful in consultation and as the scope of our activities has at times extended beyond the fairly definite initial objectives he has gladly sanctioned the larger plan. He recognized in the proposal for summer schools for engineering teachers an immediate and fruitful outcome of the investigation and his sympathetic and financial endorsement put that project into action. His further endorsement of a new proposal resulted in a contribution to the supplemental investigation of Technical Institutes which enabled our staff to render signal service in a closely related field of technical education.

(b) Funds for Concluding the Project

Upon completion of the initial three year period financed by the Carnegie Corporation and devoted largely to factfinding, it was evident that many of the benefits which should follow the work already completed were contingent upon the continued activities of the Board and Staff for a further period of two years thus rounding out the period initially planned. The headquarters of the staff were in the Engineering Societies Building and the close contact which had been maintained with the National Engineering Societies and their participation in the project had impressed them with its significance. They, thereupon, took the initiative in making contributions when funds were needed for the second period. Mr. Alfred D. Flinn, Director of Engineering Foundation, the organized research agency of the profession joined actively with the Chairman of the Board in presenting the situation to various industries and individuals interested in engineering education whose contributions supplemented that of the engineering societies in supplying funds for the completion of the undertaking.

II. PERSONNEL: THE BOARD AND STAFF; COOPERATING AGENCIES

The Society for the Promotion of Engineering Education in undertaking the present project placed the responsibility on a Board of Investigation and Coordination.

The Board

The Board has consisted of five members appointed by the Council of the Society, also the President (changing annually) and the Secretary, F. L. Bishop, ex-officio, also two non-engineering members representatives of education.

The five originally appointed members who also had constituted the Development Committee were:

Dean M. E. Cooley, University of Michigan,

Secretary J. H. Dunlap, American Society of Civil Engineers (formerly Professor, State University of Iowa),

Professor D. C. Jackson, Massachusetts Institute of Technology,

President F. W. McNair, Michigan School of Mines,

Professor C. F. Scott, Yale University.

The term of one member expired each year but he was usually reappointed to succeed himself. President McNair and Secretary Dunlap met death in a railway accident on their return from the Boulder Convention of the Society in 1924. This was indeed a sad blow to the Board as their enthusiasm and idealism and practical service were outstanding. They were succeeded by Dean F. E. Turneaure, University of Wisconsin, and Dean D. S. Kimball, Cornell University.

Dean Cooley, on his retirement from active university duties, resigned his place on the Board in 1928, which was filled by Dean R. L. Sackett of Pennsylvania State College.

Other members who have served on the Board during their term as President have been

Dean P. F. Walker, University of Kansas,

Dean A. A. Potter, Purdue University,

Dean G. B. Pegram, Columbia University.

Dean O. M. Leland, University of Minnesota,
General R. I. Rees, American Telephone and Telegraph Company.

The two members of the Board serving particularly in an advisory capacity in the field of education were President Frank Aydelotte, Swarthmore College, and Dean C. E. Seashore, University of Iowa.

President Aydelotte, with wide experience and contacts in the educational field, and Dean Seashore, expert in the field of psychology, took a keen and active interest in the work of the Board and rendered signal service in advising as to the initial policies and plans and later on in the formulation of conclusions and reports.

The Board as thus constituted has contained some members continuously which has given continuity to the enterprise. The President of the Society, changing from year to year, and the Secretary have kept the Board in close touch with the active administration of the Society, while the non-engineering members gave the Board the service of experts in the field of general education and psychology.

The Staff

W. E. Wickenden was appointed Director of Investigation in November, 1923. He had been on the engineering staffs of the University of Wisconsin and the Massachusetts Institute of Technology. In the war period he directed recruitment and education for the research laboratories of the Western Electric Company and later became Assistant Vice-President of the American Telephone and Telegraph Company, directing the educational activities of the Bell System.

Mr. Wickenden retired as Director and assumed the Presidency of the Case School of Applied Science, September 1, 1929.

H. P. Hammond was appointed Associate Director in the spring of 1924. He had been Chairman of the Committee on Educational Policy of the Brooklyn Polytechnic Institute and was therefore specially qualified to take charge of the relations with the colleges, particularly in organizing their cooperation in the assembling of data. Professor Hammond was placed in charge of the Summer Schools for Engineering Teachers (inaugurated in 1927) and in June, 1929, was designated as Director of Summer Schools for Engineering Teachers.

R. H. Spahr, of wide educational and industrial experience, served as special investigator in connection with the supplemental study of Technical Institutes. John T. Morris, formerly director of the College of Industries of the Carnegie Institute of Technology, and later a member of the Division of Higher Education of the University of Pittsburgh, aided in the studies. This work was under the general direction of a committee of which Frederick B. Pratt was chairman. The work was conducted under the immediate direction of Mr. Wickenden.

Cooperating Agencies

Reference has been made to the cooperative principle under which this investigation was conducted. Principal among the participating groups have been the following:

a. Several general committees of the Society dealing with the following subjects: Students and graduates; admissions and eliminations; teaching personnel; services, facilities and costs; economic content; cooperative courses.

b. One hundred and fifty cooperating colleges in which committees including over seven hundred individuals participated.

c. National Engineering Societies: American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and American Institute of Chemical Engineers.

d. Eta Kappa Nu Honor Society.

e. United States Bureau of Education.

f. National Industrial Conference Board.

III. The Problem

A definite statement of the problem to be undertaken and the specific objectives sought was found surprisingly difficult and baffling. When the Development Committee set about to find a way to ''develop, broaden and enrich engineering education'' it considered its task nearly completed at the end of the first half day. But on careful review its proposed resolutions appeared general and commonplace; they did not reflect the idealism and spirit of the early discussion nor did they emphasize the vital participation by which the schools were to make this undertaking quite different from the ordinary compilation of a formal report on prevailing conditions. The committee continued its deliberations for three days and held a final session a week later.

The tenor of several pages of the Report ‡ devoted to the general situation and the objectives of the project are indicated in these extracts.

''The problem of engineering education is to determine and to meet the progressive demands of a rapidly changing civilization. What constitutes these demands is a question being considered by the educators, by engineering societies, by organizations of industries and public utilities and by others. Unfortunately, there has been almost no coordination of effort, and there is lack of agreement on even fundamental objectives. The first necessity then would seem to be an investigation to determine just what the facts are. . . .

''The fundamental requirement is to investigate comprehensively the facts bearing on engineering education in its several fields and to arrange and present the results. . . .

''There shall be coordinated as far as possible the various agencies interested in engineering education.'' These ideals were emphasized by incorporating them in the descriptive title ''Board of Investigation and Coordination.'' A unique feature is found in this sentence in the list of objects for which the Board and staff were created: ''To maintain close contact with engineering schools enabling them to participate in the investigations; and reporting to them from time to time; to the end that the developments may be continuous from the initial contact between the colleges and the agencies of the Board.'' This idea is elaborated in the letter transmitting the Report of the Development Committee to the Council of the Society: "Our real function as a Society is to develop teachers who can train engineers. Real progress must come largely from inward growth. The greatest gain must come from better teachers and stronger faculties. The present plan is not something apart from the schools; it is not a scheme by which some super-committee shall evolve a solution to engineering education in a formal report. The movement contemplates active participation by the schools and the proposed organized effort should have its richest results in directing attention, awakening interest and securing participation of engineering teachers and faculties in this work."

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‡ See *Engineering Education* Bulletin of the S.P.E.E., Sept., 1922.

In our first interview Dr. Pritchett remarked that the elaborately prepared program of the Development Committee was too defuse in its aims and he proposed beginning with a specific problem, such as the curriculum.

Five months later the decisions reached in several conferences took shape in the following memorandum § which was presented to and accepted by Dr. Pritchett.

"The Society for the Promotion of Engineering Education proposes during the next three years to make a discriminating study of the present state of engineering education.

"In undertaking this work, the Society realizes the need of bringing it within a designated field in order that the investigation may lead to definite results. It is also clearly recognized that other studies on the same subject being made at this time should be related to that which the Society for the Promotion of Engineering Education has in view—particularly the investigation now under way by the National Industrial Conference Board,|| which approaches the subject from the stand-

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§ *Proceedings, S.P.E.E.*, Vol. XXXI, 1923, pp. 22–28.

|| As the outgrowth of a conversation between the President of the Society and Mr. Alexander, President of the National Industrial Board there resulted a joint committee on Engineering Education comprising representatives of industry and of the Society. A statement regarding this committee appears in *Engineering Education*, Bulletin of the S. P. E. E., Sept., 1922. Under the general direction of this committee the National Industrial Conference Board conducted a number of important investigations and issued reports, some general in char-

point of the man in industry who employs engineers and from the standpoint of practicing engineers themselves. The inquiry proposed by the Society is primarily from an educational point of view.

''It is therefore proposed that the investigations of this Society be directed to a study of the objects of engineering education and the fitness of the present-day curriculum for preparing the student for his profession. It will study the process by which the curriculum of fifty years ago has come to its present form; it will seek to set forth the nature and the weakness of the curriculum as at present administered; and it will indicate such modifications or developments as would seem to make for sound, well-balanced, and fruitful course of study of engineering students.''

The memorandum also proposed that the inquiry should be carried on by a Board appointed by the Society and containing two non-engineers ''whose point of view will be primarily that of the trained teacher''; a Director should have active conduct of the study, organizing cooperative committees in engineering faculties and visiting European engineering schools.

Beginning in the Fall of 1923 the newly appointed Director of Investigation devoted much time during the first year to reconnaisance, visiting schools and interviewing students in a search for common aims and ideals to be incorporated in the explicit program for betterment of engineering education. He counselled with members of engineering societies and industry. He compared engineering with other professions and engineering education with other types of education. A study of ''the objects of engineering education'' as a necessary prerequisite to the determination of curricula *did not however,*

acter and others relating to specific industries. These include papers presented to the Society as follows:

''The Engineering Graduate in Industry,'' A. C. Jewett, Vol. XXXII, 1924, p. 424.

''The Engineer as a Leader in Industry,'' O. S. Lyford, Vol. XXXI, 1923, p. 136.

''The Problem of Engineering Education from the Standpoint of American Industry,'' M. W. Alexander, Vol. XXXIV, 1926, p. 586.

converge on a definite point, but seemed *to open up an unbounded area.*

IV. BROADER OBJECTIVES OF THE INVESTIGATION

The expanding functions of engineering in modern life and the enlarging activities of engineering graduates in semi-technical and administrative fields indicates that engineering education prepares for a far more comprehensive field than that of specific professional practice.

During the very decade in which we have been making our studies and trying to get our bearings progress has been so phenomenal as to justify a commission headed by Mr. Hoover to report upon recent economic changes in the United States. The unprecedented acceleration in recent economic developments is based on engineering achievement.

It is one thing to determine how the engineer should be trained to do the things which tradition and past practices have prescribed as his normal work. It is quite another thing to picture his place in the New Epoch which power and machinery, science and engineering and productive industry is initiating.

In our new industrial, our so called ''machine'' civilization, our modern life has become more complex and its activities are on a far larger scale and are more intimately interrelated. A student of modern trends says that even the axis of our civilization has shifted. The direction of the new economic forces which are shaping our modern life is passing from the field of politics into that of economics. As emphasized by Dean Kimball in his recent presidential address before the Society the new conditions in which production exceeds needs, in which working hours are reduced and the hours of leisure are increased, in which for the first time in history it is possible to eliminate poverty and to provide a competence for all and in which universal education is open to all—all these things are the outcome of the application of science by the engineer. It is not surprising, therefore, that the functions of the engineer have become more complex and are interrelated with many activities of modern life. Engineering education must deliberately provide the way for the solution of problems in the field of social utility as well as the application of scientific principles to specific technical problems. The strictly technical professional activity is comprised in engineering but it is not a definition of it. What engineering education must have is a guiding philosophy based on a clearer visualization of the place of engineering in modern life.

It was this problem which challenged the Society in its study of engineering education. One's conception of the field expands as he explores in this country and abroad the professional, technical, industrial and social significance of engineering in the new economic order. We have endeavored to clarify the situation, not by attempting to draw conclusions so rigid that they may be formulated in precise rules but rather by presenting the underlying facts and the views and conclusions resulting from the general study of the situation. Dr. Wickenden's report in particular epitomizes the results of the intensive study of engineering education for which this investigation has afforded unusual opportunities.

In engineering education we seek a unity of purpose rather than standardization. This report aims to present the problems involved in training the engineer of the future in such form that every school and every teacher may find the guiding principles by which to shape the best individual solution as a contribution to our continuously expanding civilization.

V. Conclusion; Future

During the progress of the investigation it became increasingly evident that engineering education cannot be cast in a fixed mold. Engineering educators must be alert to meet the conditions created by fruitful scientific research, expanding industry and the enlarging dependence of modern life upon engineering activities. The work of the Board has demonstrated that the faculties of engineering schools can cooperate effectively in dealing with the problems of engineering education when aided and guided by a central directing board and staff. It is to be assumed that individual educators and faculties will be alert to the changing problems which confront engineering education, but our experience makes clear to us that the best results can be obtained, and obtained most economically in the long run, by concerted action through a central agency. Certainly the effective coordination of 150 engineering schools, when they are called upon to deal with the professional engineering societies and various industrial groups, calls for such a central agency. Furthermore, our present general scheme of technical education emphasizes certain types to the neglect of others. A balanced National policy by which the various branches of technical education may meet the needs of our changing industrial and economic life calls for coordinated efforts of many groups.

In presenting its report in final form the Board believes that the survey of the situation and the resulting interest and constructive activity on the part of engineering schools constitute a substantial contribution in answer to the question, What can the Society do in a comprehensive way to develop, broaden and enrich engineering education? What has been accomplished is not to be regarded as a completion of the task but rather as the first step in dealing with a continuing problem.

Two auspicious things have occurred which promise continuation of certain important features. The Society has undertaken to continue the Summer Schools for Engineering Teachers which were proposed and inaugurated by the Board, thus putting into practical operation an affective means of developing engineering teachers, which is the key to the problem of developing engineering education.

Secondly, a new study of the status of engineering education has been undertaken for determining the progress that has been made since the survey conducted by the Society through its Board and Staff was completed. This will afford a comparison over a five year period. At the request of the Society for the Promotion of Engineering Education the United States Bureau of Education is conducting this survey. Blanks issued to the schools were accompanied by a letter, January, 1930, signed by William John Cooper, Commissioner of Education. This recognition and cooperation is a significant achievement.

The Board believes that the type of activity it has initiated should be continued. While much may be accomplished by individuals and faculties, engineering societies and industrial leaders to all of whom engineering education is of vital importance, it is believed that a formal representative general agency, possibly an Engineering Education Foundation, would be of outstanding value in developing continuously engineering education as a potent factor in the progress and stabilization of a civilization based upon machinery and power and applied science.

CONTRIBUTORS TO FUND FOR IMPROVEMENT OF ENGINEERING EDUCATION

Carnegie Corporation
Carnegie Foundation
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American Society of Civil Engineers
American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers
American Society of Mechanical Engineers
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Purdue University
Western Electric Company
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Purdue University
Western Electric Company
Westinghouse Electric & Manufacturing Company
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Yale University

SUMMARY OF THE FACT–GATHERING STAGES OF THE INVESTIGATION OF ENGINEERING EDUCATION.*

BY H. P. HAMMOND,

Associate Director of Investigation.

It has been an avowed principle of the Society's Investigation to proceed to conclusions upon the basis of well-established facts. During the past two years we have been engaged in gathering those facts. Paralleling the facts we have assembled a body of opinion on essential elements of engineering education. As the facts and opinions have become available they have been distributed to our coöperating committees whose work for the past year has been devoted chiefly to a careful study of the evidence and to the formulation of conclusions and recommendations. A portion of the material has been published. The committees have reported their recommendations at this convention. Eventually all of the material will be consolidated into an organized series of documents which it is hoped will assist in shaping the future course of engineering education. To date no single summary of the material has been made. It may therefore be appropriate at this time, which marks the essential completion of this stage of the Society's undertaking, to present such a summary. The purpose will be to bring together into a condensed statement those portions of the body of facts and opinions which appear to be of most fundamental importance and to give a comprehensive picture of the whole.

ORGANIZATION.

The Society's Investigation differs in one important respect from earlier studies of education for the professions; namely,

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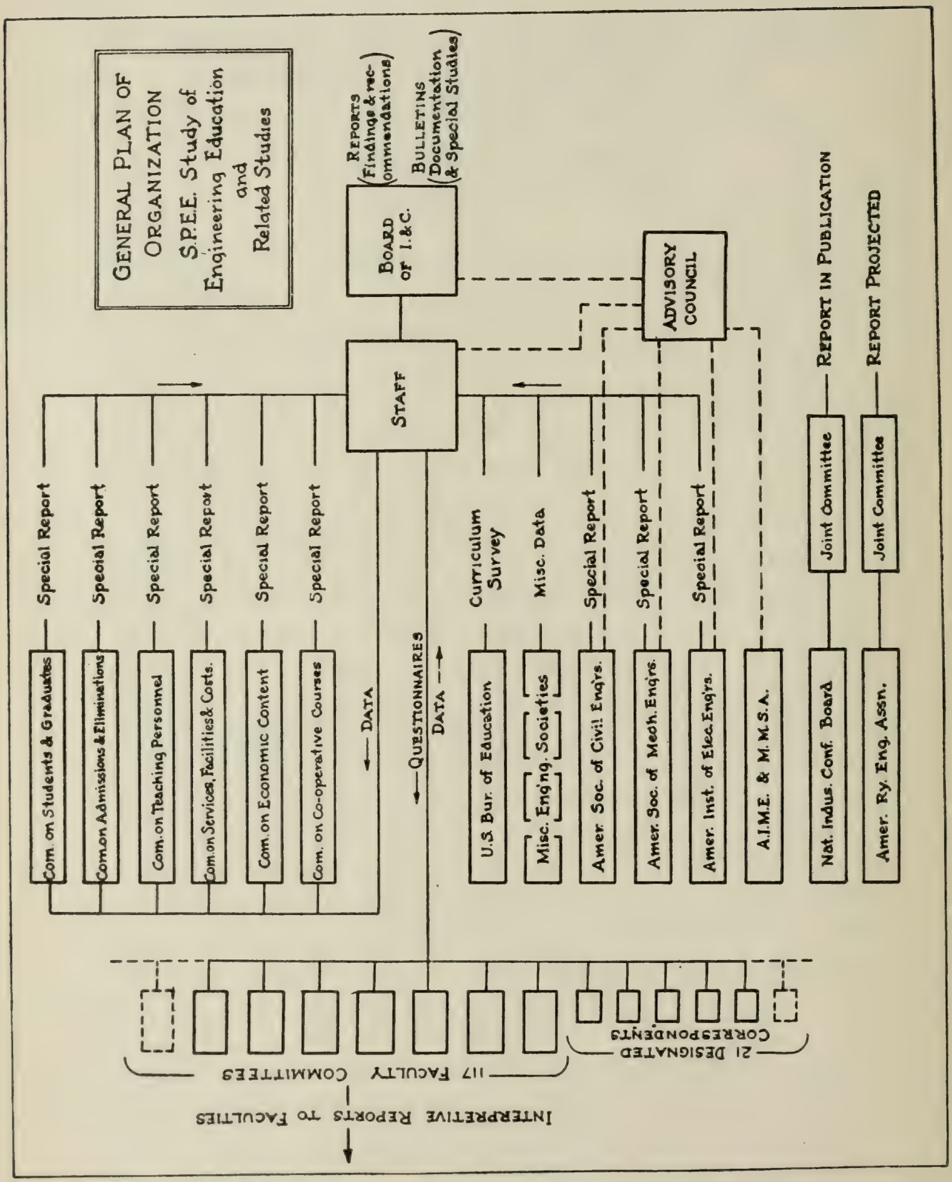
* Presented at the 34th annual meeting of the Society for the Promotion of Engineering Education at the State University of Iowa, June 16–18, 1926.


GENERAL PLAN OF ORGANIZATION
S.P.E.E. Study of Engineering Education and Related Studies
Board of I. & C.
Reports (Findings & recommendations)
Bulletins (Documentation & Special Studies)
Staff
Advisory Council
Com. on Students & Graduates
Special Report
Com. on Admissions & Eliminations
Special Report
Com. on Teaching Personnel
Special Report
Com. on Services, Facilities & Costs.
Special Report
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Data
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Curriculum Survey
Misc. Engng. Societies
Misc. Data
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Nat. Indus. Conf. Board
Joint Committee
Report in Publication
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Joint Committee
Report Projected
117 Faculty Committees
21 Designated Correspondents
Interpretive Reports to Faculties

Fig. 1

in the method of conducting it through the coördinated activities of committees of the Society and committees of the faculties of the colleges. Since the plan of organization of the work is in itself an essential feature of the undertaking, and since there were no precedents in formulating such a plan, the one followed is here included as a matter of record.

Figure 1 shows graphically the relationship of the various organizations, committees, and individuals which have been engaged in the work, as well as the routing of communications, data, and reports between those bodies and the Board and Staff. The relationship of the related studies made by the national engineering societies and industrial groups is also indicated. It is probably accurate to say that without some such definite plan of organization, an undertaking of similar character and magnitude would soon disintegrate into a hopeless chaos of undirected effort.

In addition to a plan of organization of coöperating agencies, there has been a definite organization of the several parts of the study itself. The various projects which have comprised it have been grouped in five principal divisions as follows:

1. STUDIES RELATING TO PERSONNEL—STUDENTS, GRADUATES AND TEACHERS.
    - *a.* Entering students.
        - Geographical sources.
        - Scholastic sources and levels of attainment.
        - Social, economic and cultural groups represented.
        - Conditions of educational and vocational choices.
    - *b.* Admission requirements and practices.
        - Extent and variety of entrance requirements and supplementary tests.
        - Results of admission with conditions.
        - Types of admission procedure.
        - Present status of the art of selection.
        - Public regulations in tax-supported institutions.

- *c.* Survival and elimination.
  - General trends over a twenty-five year period.
  - Variations among regions and types of institutions.
  - Reasons for eliminations, by statistical and clinical inquiries.
  - Diagnostic methods and remedial measures.
  - Methods of orientation.
- *d.* Transition of graduates to practical life.
  - Employment procedure.
  - Types of work entered.
  - Introductory training and continuation of study.
  - Shifting between positions.
  - Compensation in early years after graduation.
- *e.* Careers of graduates and non-graduates of maturity.
  - Types of work and responsibility.
  - Stability, migration and evolution.
  - Earnings.
- *f.* Teaching personnel.
  - Sources from which engineering teachers are drawn.
  - Losses to other forms of work.
  - Teaching and other work loads.
  - Academic qualifications of teachers.
  - Professional practice and collateral activities of teachers.
  - Earnings and economic status of teachers.

2. STUDIES OF CURRICULA AND METHODS OF INSTRUCTION.

- *a.* Curricula and graduation requirements.
  - Present curricula in the several professional branches.
  - Credit requirements.
  - Historical backgrounds and evolution.
- *b.* Degree usage.
  - For undergraduate courses.
  - For graduate work in residence.
  - For professional work.

c. The Cooperative method of engineering education.
    Inception and general data.
    Organization and administration of cooperative courses.
    Appraisal of value of the cooperative method.

d. Placement examinations and sectioning on the basis of ability.
    Purposes and functions of placement examinations.
    Validity and reliability.
    Results—indications of individual differences, prediction of performance, results of trial of the examinations in various institutions.
    Limitations.
    Sectioning on the basis of ability—methods and results.

3. STUDIES OF SUPPLEMENTARY SERVICES OF THE ENGINEERING COLLEGES AND OF THE COSTS OF ENGINEERING EDUCATION.

a. Services and facilities of engineering colleges.
    Evening, short-term, extra-mural and correspondence courses.
    Graduate courses, fellowships and organized research.
    Testing and consulting services.
    Present student capacity of the colleges.

b. Costs of engineering education.
    Operating costs.
    Revenues.
    Investment in plant and endowment.

4. STUDIES OF THE RELATIONSHIP OF ENGINEERING EDUCATION TO THE PROFESSIONS AND TO THE AMERICAN INDUSTRY, AND COMPILATIONS OF OPINIONS CONCERNING ENGINEERING EDUCATION.

a. Occupational needs and specifications in industry.
    Manufacturing industries.

- Transportation industries.
- Communication industries.

b. The professional patterns in major and minor engineering fields.

- Composition and activities of professional groups.
- Common core of knowledge in each major division.
- Specialization in each major division.
- Occupational demands in special divisions of engineering.

c. Appraisal and criticism of college training by graduates and former students.

- Principal elements of value.
- Omissions and defects.
- Types of improvement and development needed.

d. Opinions of engineering teachers as to the engineering curricula.

- Diversity of curricula.
- Common core of essentials.
- Instruction in economics and in administration and management.
- Cultural subjects.
- Shop courses.
- Coordination of various subjects of curricula.

e. Opinions of professional engineers concerning educational policies and practices.

- General inferences and conclusions.
- Opinions concerning curricula and educational methods.
- The influence of the national engineering societies in engineering education.

5. STUDIES OF ENGINEERING EDUCATION IN EUROPE.
   - Historical development of engineering education.
   - National plans of organization.
   - Curricula and teaching methods.
   - Relation to preparatory education.

Relations to professional organizations.
Relations to industry and public service.

In each of these divisions the various studies have been conducted as a series of individual but related projects, each planned and carried out as a unit. In so far as advisable the work has been definitely systematized. It has been recognized, however, that an undue emphasis on systematic and orderly arrangement might, if carried too far, obscure those less tangible but vitally important factors which are found throughout educational work. This has never been lost sight of and while, for purposes of summation and comparison, much of the material has been reduced to statistical statement, the limitations of figures have always been taken into consideration and weight given to those aspects of the problems which cannot be expressed statistically.

Such, in brief, have been the principles and methods by which the undertaking has been planned and conducted. The results of the studies of the first three of the above mentioned divisions will now be reviewed.

PERSONNEL.

The personnel factor has a vital bearing upon all educational problems. Questions of what to teach and how to teach must be answered in the light of to whom and by whom the teaching is done. Studies of personnel are always difficult to formulate and it is impossible to reduce them entirely to a basis of statistics. Such studies have nevertheless had an important place in the Investigation and the results have furnished a foundation of fact which has assisted materially in the consideration of all of our problems.

Students.—The data before us seem to show plainly that, on the whole, students entering engineering colleges are as good material, fundamentally, as we could hope to expect. They come for the most part from sound stock and appear to be of good intellectual ability. Their records and preferences in high school subjects, as shown by their own statements and as confirmed in certain instances by high school records, show that we are attracting our full share of young men from the upper levels of scholastic ability and that our students have done well in those subjects which constitute the essentials of preparation for engineering curricula. Our students appear for the most part to come from homes of modest means. The facts that but 13 per cent. of their fathers and 5 per cent. of their mothers have college degrees; that but 40 per cent. of the parents are high school graduates; that another 40 per cent. have a grammar school education or less; and that 4 per cent. of their fathers are engineers, while not to be taken in any derogatory sense, nevertheless have an important bearing upon our problems.

While in many respects the evidence relating to students must cause gratification, there are many aspects of it which cannot but give us concern. For one thing it is *unmistakably clear* that neither the extent nor the quality of their preparation is satisfactory as a foundation for an engineering education.

One of the most serious aspects of the matter of student personnel appears to be that our students choose engineering as a career in most cases without adequate understanding of what engineering is or what an engineering education requires. It seems clear that many young men are admitted who, while endowed with good native intelligence, do not possess those qualities which successful pursuit of an engineering curriculum and an engineering career demands. Our students appear to make their choice of a career at an early age—more than half before entering the last year of high school—largely on the basis of their own judgment, influenced only to a minor degree by advice from parents and teachers. If many students thus choose engineering on an imperfect basis of knowledge, it is probable that many a young man possessing the necessary qualities chooses against engineering on equally casual grounds. If the colleges are to continue, as seems probable, to articulate their curricula with those of secondary schools and to admit the great majority of students on cre-

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N. C. State College

dentials, the most promising means of remedying this situation seems to rest in the wide dissemination of accurate information upon which the prospective student may make his choice. Steps in this direction are being taken and it is hoped that they will be carried out speedily and effectively. A note of caution in this connection may perhaps be sounded. If the impression is given that an organized propaganda in favor of engineering education with the purpose of increasing enrollments is in progress, it is entirely possible that our efforts will yield nothing, and even that they will react against us.

Admission and Elimination of Students.—Methods of admission to engineering colleges and curricula are too well known to need repetition. The status of engineering as an undergraduate program appears to be firmly established and it is seriously to be questioned whether it would be desirable to change it. To do so would doubtless relieve us of much of our admission problem and would probably serve to furnish us with a much more highly selected body of students. But were the engineering colleges to require two or more years of general college courses for admission, they would transfer to others much of the training in mathematics and science which should coördinate so closely with work in the engineering subjects proper. It is very doubtful whether such a change would be for the better.

If we are to continue to admit our students directly from the secondary schools, basing admission methods primarily upon presentation of credentials, published entrance requirements seem to be as high as conditions warrant. It is a very significant fact, however, that nearly one fifth of all students entering in 1924 were admitted with entrance conditions, and that one eighth were conditioned in mathematics. It is clear that admission requirements are not actually as high as published statements would indicate. The effect of this large proportion of admissions with conditions is undoubtedly to "nullify the real and potent influence a fixed standard may exert."

The situation as to eliminations may be briefly summarized as follows: Of every one hundred students admitted to engineering curricula, approximately 38 survive to graduate. Of the 38, approximately 28 complete the course regularly in the specified period. This ratio of graduations to admissions is the lowest of any division of collegiate work for which figures could be obtained. The chief causes of eliminations, as obtained from certain colleges which keep such records, appear to be poor preparation (in which admission with conditions is an important factor), lack of ability and lack of interest (to which, probably, should be added poor teaching); these causes combined being the chief factors in nearly 70 per cent. of the cases. It should be remembered that statements obtained from students who did not graduate confirm the figures obtained from the colleges. Health, finances, athletics, and social diversions; all of which have an effect upon scholastic work, as well as being in themselves direct causes of eliminations; appear not to play as important a part in the situation as might have been expected.

If as previously stated the status of engineering as an undergraduate program seems likely to continue, we shall no doubt continue to have a high ratio of eliminations. It seems clear that the inherent difficulty of engineering courses, their demand for close analytical thinking, together with the plain necessity that the colleges shall continue to safeguard the standards of the engineering profession will always act to cause the elimination of many students. But it seems equally clear that we may well endeavor to reduce our eliminations as much as may be possible and proper.

A first and fairly obvious step in that direction would seem to be a reduction in the numbers admitted with conditions. In 1924–25 eliminations among students admitted with conditions in mathematics was 60 per cent. greater than among those admitted with clear records. A second step would seem to be the gradual introduction, in colleges where such requirements are possible, of more selective methods of admission. Tests of aptitude, as well as of scholastic training, appear to offer promising possibilities in this connection.

It will not be possible within the limits of this report to discuss the question of whether or not more definite provision can be made for the needs of students who cannot continue to graduation. This matter has been touched upon by the Committee on Engineering Students and Graduates and will be discussed in the report of the Director.

Graduates.—Many of the data regarding our graduates are distinctly encouraging. It is gratifying to learn that assertions to the effect that a great majority of engineering graduates leave the profession for other fields are not based upon fact and that the actual situation is quite the reverse. The steady advancement of graduates through positions preponderantly technical in nature to those involving administrative and executive responsibility, as disclosed by the figures, seems to point clearly to the essential soundness of engineering education and to the fact that technical training provides an adequate and proper foundation for the direction of American industry. Whatever may be said to the contrary, the earnings of engineering graduates appear to be good. It may be said at this time that our published figures on earnings have been subjected to every practicable check and that no appreciable discrepancies have been discovered. In fact studies made independently confirm our figures. It is probable that they give an essentially accurate picture of the situation.

With relation to our graduates two large and relatively undeveloped fields of opportunity are disclosed; one relating to the selection of first positions after graduation, and the other to the possibilities of assisting graduates in educational work after leaving college.

The demand for engineering graduates appears to be good; in fact at present all of the best men can usually choose between several offers and very few have any difficulty in finding positions. Yet, from the evidence, a large proportion seem to select positions for which they are not fitted or choose lines of work which do not provide the type of employment or the opportunities which they hoped to find. The situation is in many ways similar to that mentioned previously in relation to the selection of engineering as a career by the prospective student. The most promising way to seek for improvement seems to be similar in the two cases; namely in the endeavor to provide adequate knowledge upon which decisions may be based. Ways in which this may be accomplished have been pointed out by the Committee on Engineering Students and Graduates. They do not seem to present any insurmountable obstacles and it is hoped the colleges will adopt them.

It is often said that a college course does not complete an engineering education. This statement is amply confirmed, if confirmation be needed, by the evidence as to the extent to which graduates more or less systematically pursue some line of study after leaving college. There appears to be a large and undeveloped field of opportunity in this connection. Some of the institutions are awakening to the possibilities and references to extension work among graduates are becoming increasingly frequent. There would seem to be no reason why the engineering colleges should not take a full and active share in this movement, in fact the need for it in engineering is probably as great, if not indeed greater, than in any other profession.

Teachers.—As far as statistics can picture the situation as to engineering teachers, the conditions seem to be healthy—with one or two important reservations. The data indicate that engineering colleges draw their teaching staffs from sufficiently diversified sources, that the annual losses are not unduly large, that the teaching load is well distributed among teachers of various ranks, in short that there is a condition of normal and desirable stability.

When one considers, however, the attractions of the teaching profession in contrast with a career in professional or industrial work, the conditions seem far from satisfactory.

On the average, engineering teachers spend 18 hours per week in classroom or laboratory instruction. This is known to be considerably larger than in other college courses. If this figure represents the *average,* loads carried by many teachers must be greater. When the incidental duties of every engineering teaching position are added, the total is a load so great as to make it extremely difficult in many cases for the teacher to have that opportunity for growth and development which is so essential. This condition seems to apply especially to the younger men.

The matter of teaching salaries has been discussed so often and is so much in the public mind as hardly to need attention here. Yet the situation disclosed by the comparison of earnings of teachers and engineering graduates is one which cannot be passed without comment. Until it is remedied, it would seem impossible to go far in raising the quality of our instructing staffs to those levels which the importance of engineering demands. The Committee on Teaching Personnel has presented these facts and recommends a scale of salaries which seem to be commensurate with the real needs of the situation. To many these figures must seem beyond the possibility of realization. It must be remembered, however, that the highest of the proposed figures are not greater than those of positions of equal rank in other professional branches in a rather considerable and a growing number of institutions. Certainly they are not beyond the needs of a life of modest comfort. It may be pertinent to compare the salaries proposed with those already in effect.

Teaching Rank.	Present.		Proposed.	
	Min.	Max.	Min.	Max.
Instructor	$ 900	$3,000	$1,500	$3,500
Assistant Professor	1,500	5,000	4,000	5,500
Associate Professor	2,000	6,000	6,000	6,500
Professor	2,500	7,500	7,500	12,000

It is apparent that the increases in the maximum figures are small, being about $500 per year for each rank. The largest increases apply to the minimum salaries now paid. It should be remarked, however, that there are more salaries at present near the minimum figures than there are near the maximum ones.

Supplementary Activities of the Engineering Colleges.

The Committee on Services, Facilities and Costs has presented tabular summaries of data relating to activities of the engineering colleges other than those directly connected with undergraduate instruction. The data relate to three principal types of activities: graduate courses; extension, short-term, evening and extra-mural courses; and research.

The number of graduate students of engineering is gratifyingly large; the number reported by the United States Bureau of Education for the present year being 1,114. This is approximately one eighth of the number of first degrees conferred in the preceding year. This growth of graduate work in engineering is undoubtedly highly desirable. The provision of graduate courses in institutions equipped and manned to give them properly, and the election of such courses by those students who have the inclinations and qualifications to pursue the more advanced stages of engineering education in college, would seem a logical development if four years is to continue to be the normal length of the undergraduate curriculum.

The very considerable amount of work done by the colleges in short-term courses, extra-mural courses, extension courses and the like would seem to indicate appreciation of the fact that the demands of industry for technically trained men are by no means confined to engineering graduates and that the engineering colleges may serve a distinctly useful purpose in providing opportunities for such work. The total number of registrations in courses of these types, not including evening courses leading to degrees, during the year 1924–25 was 20,078 which is approximately four tenths of the enrollment in the regular full-time degree courses. Since the average duration of these special courses is short—probably less than two years on the average—it is apparent that the total number of individuals benefited by work of this character is nearly if not quite equal to the number of regular undergraduate students. Until more general provision for work of this character is afforded by technical institutes of a rank intermediate between secondary schools and colleges it would be entirely desirable for the engineering colleges themselves to continue the work.

RESEARCH.

During the year 1924–25 the colleges in the United States expended approximately $1,500,000 on research (including amounts expended in colleges which do not carry research funds as a separate budget item). At first this figure may seem large. It must be remembered, however, that it is but five per cent. of the amounts expended for undergraduate instruction; furthermore, ninety per cent. of the expenditures were made by but twenty-two institutions. While the extent and value of research work can not, of course, be stated entirely in terms of dollars, it is thought that the figures give a fair indication of the place which research has in the activities of the colleges. It appears to be a subordinate activity. The primary function of engineering in the colleges is undoubtedly the training of undergraduate students. Nevertheless, the contribution to knowledge through research is a matter of major importance. Furthermore, as pointed out by two of the committees which have reported, research activities have a vital bearing upon the development of teaching staffs, serving as they do to give opportunity for original work. More generous provision for research would seem to be highly desirable.

COSTS.

The data on costs which have been presented are believed to be a valuable contribution to the Investigation. The cost per engineering student per year averages approximately $610, including interest on plant. Of this amount, the proportion paid by the student, on the average, is $172 per year. The total annual cost of engineering education in this country is in the neighborhood of $30,000,000—a very sizable total. It may well be asked whether funds needed to raise the standards of the colleges should not be provided by assessing a greater proportion of the cost upon those most directly benefited.

One significant point in connection with costs is that the cost per student per year and expenditures per student graduated in the privately endowed universities are equal to or even greater than those in the privately endowed polytechnic institutes. From this it appears that there is no considerable economy in operating expenses in providing instruction for engineering students in the general academic departments of the universities as compared with the provision for such instruction within the engineering college itself, though there are obvious limitations to the application of such a general statement.

CURRICULA.

The engineering curriculum may be characterized as a combination of academic and professional study, occupying a middle position between the more strictly professional curricula of medicine and law and the purely academic curricula of colleges of liberal arts. Engineering educators recognize the necessity of providing adequate training in the fundamental sciences and English and of giving the student some appreciation of the cultural elements of education, as well as providing a foundation of knowledge and a command of the essential technique and skills of engineering.

Based as it is upon the preparation afforded by a high school course providing only moderate emphasis on the essential training in mathematics and science, a considerable portion of the work of the early years of the engineering curriculum must of necessity be devoted to what, in a broad sense, may be regarded as preparatory training. This, together with what seems to be the desirability of graduating the majority of students after not more than four years of college work, has resulted in the compression of a heavy load both of subjects and of subject matter into the curriculum.

The present median requirement for graduation is about

144 semester credit hours. On the basis of units, this is equivalent to nearly five years of an ordinary academic course, and it is probable that engineering teachers and engineering students alike would feel that, unit for unit, the engineering curriculum is the more difficult. This fact, as previously stated, seems to be a major cause of our high elimination ratio.

The multiplication of curricula has gone on steadily since the early years of engineering education. At present no fewer than forty-seven different undergraduate courses are listed by the United States Bureau of Education. It is worth noting that seven eighths of the entire enrollment for the present year is in the five major curricula: electrical, civil, mechanical, chemical, and mining and metallurgical, and that one half of all the curricula have total enrollments of less then 100 students each.

A considerable proportion both of subjects and of subject matter is common to all curricula. The following tabulation gives the proportion common to all curricula in the various institutions:

Per Cent. Common Subject Matter.	Per Cent. of All Institutions.
20–30	2.6
30–40	6.1
40–50	8.7
50–60	34.8
60–70	24.4
70–80	13.0
80–90	7.8

This common portion of the curriculum comprises English, other cultural studies, economics, and the essential mathematical and scientific subjects which underlie all engineering. It also generally includes mechanics and hydraulics, and in a number of institutions such subjects as shop, elementary surveying, elementary electrical engineering, steam engines, and the like.

Evolution of Curricula.—An interesting discussion of the evolution of engineering curricula appeared in the June, 1926, number of the JOURNAL. The diagrams accompanying the article show the gradual shift from subjects of a general nature to specific engineering subjects. It is interesting to note that in chemical, civil and mining engineering this tendency to concentrate on subjects in the particular engineering field of the curriculum has been passed and that we are now beginning to swing in the other direction; whereas in mechanical engineering the content of specific engineering subjects seems to be remaining about constant, and in electrical engineering increase of emphasis on the technical subjects still continues.

It is interesting and significant to note the gradual decrease in mathematics in spite of a well marked simultaneous decrease in the content of mathematical preparation of entering students; the early decrease and later stabilization of the content of English; and the steady decrease in modern foreign languages. In fact this latter is one of the most striking features of the diagrams. Economics has had some growth, apparently at the expense of history and political science. After a sudden increase in time devoted to shop work in the early years, the amount of this work has gradually decreased, except in mechanical engineering. Graphics has decreased almost as sharply as modern languages. The losses suffered by these two divisions appear definitely to have been gained by engineering subjects in the special field of the curriculum. Mechanics and hydraulics appear to have attained a stable position at about 1885 and to have maintained it since then.

Organization, Unity, and Sequences of Engineering Curricula.—Figure 2 is intended to show graphically one very important feature of engineering curricula, namely the essential unity of structure and the necessary interdependence and sequence of subjects. Because it shows these features quite clearly, the civil engineering curriculum has been chosen as an example.

The various subjects shown in the diagram were chosen from a compilation of opinions of engineering graduates, engineering teachers, and a selected group of prominent members of three national engineering societies. More detailed statements regarding these compilations of opinion will be given later in this report. For the present it is merely necessary to state that the subjects shown by Fig. 2 represent the consensus of opinion as to what should constitute the civil engineering curriculum. Four of the spaces are shown surrounded by dotted rather than full lines. This is for the reason that these subjects were not specifically mentioned in a majority of the replies but are included because it is the evident intent of those canvassed (as shown by statements throughout their questionnaires) that such provision should be made.

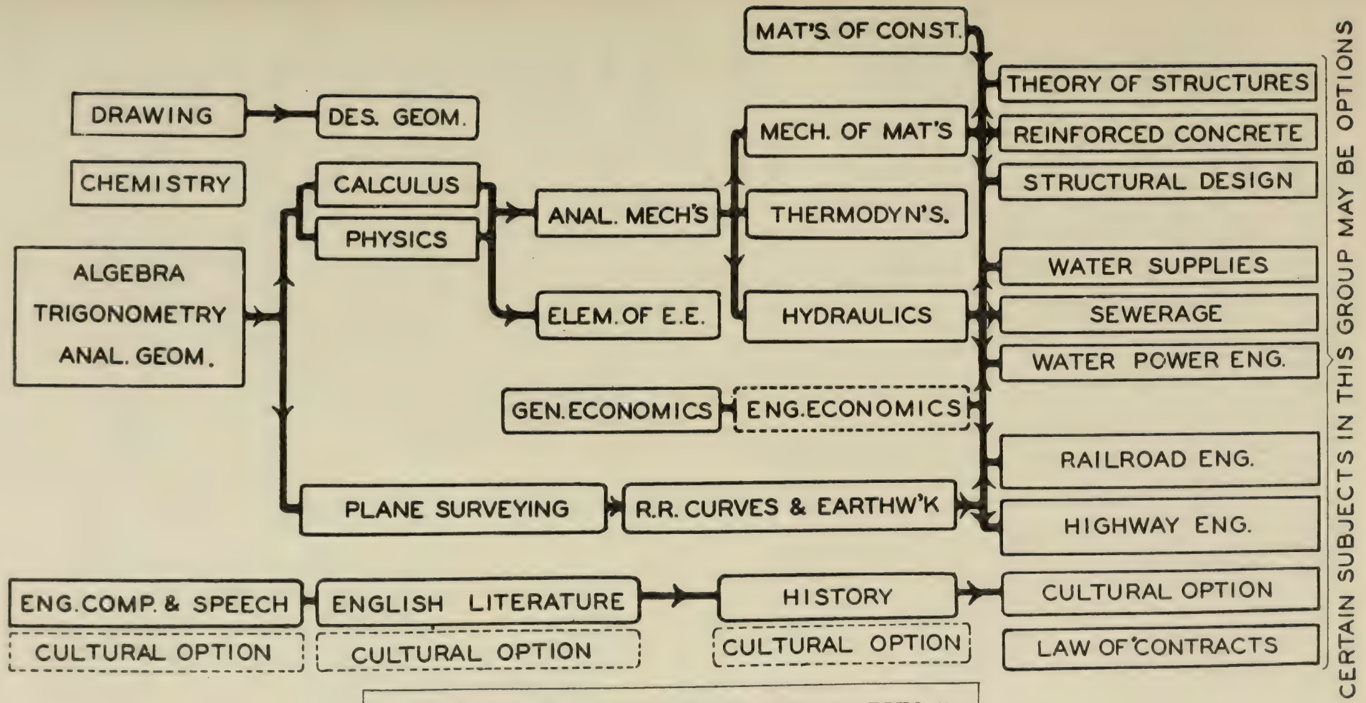
The major stems of the curriculum are shown near the center of the diagram. It will be noted that the foundation consists of the content of mathematics and physics. Branching at the end of the mathematics of the freshman year is a stem consisting of plane surveying, railroad surveying, railroad engineering and highway engineering. These subjects follow each other in logical order and each is in turn dependent upon those which precede it. Also following the elementary mathematics are the advanced mathematics and physics. The foundation material is thus continued another stage in this stem. Based upon the advanced mathematics and physics is the work in applied mechanics, mechanics of materials and hydraulics. Mechanics of materials in turn leads to structures, reinforced concrete, structural design and allied subjects; while hydraulics forms the basis of study in water supplies, sewerage and water power engineering. General economics and engineering economics are shown as foundation subjects bearing somewhat the same relationship to the entire group of professional subjects as do pure and applied mechanics. This relationship, in the speaker's opinion, is one of primary importance, though at present it is probably more a fond hope than a reality.

There are, of course, interrelationships of subjects which are not shown by the diagram. Surveying, for example, serves as a tool in lines of work other than railroad and highway engineering, and is in itself, particularly in its higher branches, a recognized subdivision of the general field of civil engineering. These interrelationships were omitted, however, in order to avoid complicating the diagram.

Similar diagrams could be prepared in other curricula. In electrical engineering, for example, mathematics, physics, mechanics, electricity and magnetism, direct and alternating currents, dynamo electric machinery, power generation and transmission, communications, and illumination exhibit the same characteristic relationships and sequences.

This organic structure of the engineering curriculum is one of its most valuable characteristics. Subjects follow each other in logical order and the student is led from broad general principles, first to general, and then to more specific applications. Each part reinforces and amplifies the others. From an educational standpoint we have in this fact an immense advantage. Fundamental principles, really comparatively few in number, underlie large portions of the work. Without a grasp of these principles and the ability to apply them, the student cannot, or at least should not, procede. In the opinion of the speaker this structural unity should never be lost sight of. The admixture of bits of this, that and the other minor subject is destructive to it, and while many such subjects are possibly of value in themselves, they do not contribute to the essential whole. The speaker also believes that concentration to a reasonable degree upon these essential subjects should constitute the cardinal principle of curriculum construction. It may be contended that the application of such a principle would lead to undue differentiation or to ''specialization.'' A moderate degree of differentiation between curricula seems not to be undesirable. Opinions which we have gathered agree on this point. Sufficient differentiation of the major curricula to permit concentration upon such a logically related group of subjects as those shown would seem to be perfectly sound.

Studies of curricula planned according to this principle indicate that subjects of the freshman year can be common to


DRAWING
DES. GEOM.
CHEMISTRY
ALGEBRA
TRIGONOMETRY
ANAL. GEOM.
CALCULUS
PHYSICS
ANAL. MECH'S
ELEM. OF E.E.
MAT'S. OF CONST.
MECH. OF MAT'S
THERMODYN'S.
HYDRAULICS
GEN. ECONOMICS
ENG. ECONOMICS
PLANE SURVEYING
R.R. CURVES & EARTHW'K
THEORY OF STRUCTURES
REINFORCED CONCRETE
STRUCTURAL DESIGN
WATER SUPPLIES
SEWERAGE
WATER POWER ENG.
RAILROAD ENG.
HIGHWAY ENG.
ENG. COMP. & SPEECH
CULTURAL OPTION
ENGLISH LITERATURE
CULTURAL OPTION
HISTORY
CULTURAL OPTION
CULTURAL OPTION
LAW OF CONTRACTS
CERTAIN SUBJECTS IN THIS GROUP MAY BE OPTIONS

RELATIONSHIP AND SEQUENCE OF SUBJECTS IN CIVIL ENGINEERING CURRICULA

FIG. 2

all courses. Differentiation can start either at the beginning, middle or end of the sophomore year. During the junior year all curricula may have certain elements in common, and this may continue into the senior year. After the middle of the junior year, however, many of the subjects would be pursued by one, or a few, groups of students only. This, to the speaker, does not seem to be specialization; nor does it necessarily mean that students need be trained narrowly. It means simply that there is opportunity for that degree of concentration which is essential to thoroughness. Curricula made up largely of miscellaneous unrelated fragments chosen with a view to giving the student some acquaintance with a considerable range and variety of material would seem to make such thoroughness extremely difficult to attain.

Opinions Regarding the Curriculum.—As previously stated, studies of personnel were among the first to be undertaken. This was done not only because of the difficulty of formulating, conducting and recording them; but also because it was believed that their results should form the necessary background from which to study the curriculum problem. With the results of the personnel studies available, with knowledge of the limitations and possibilities which those results indicated, the staff has devoted much of its attention during the past year to study of the curriculum. In pursuing that study an effort has been made to obtain the benefit of the advice and opinion of those deemed qualified by reason of interest, knowledge, and experience to express themselves.

Questions regarding the curriculum have therefore been submitted to our graduates, to selected prominent engineers in three of the major national engineering societies, and to members of engineering faculties throughout the country. Hereafter these three groups will be referred to as ''graduates,'' ''engineers,'' and ''teachers'' respectively. Their replies to questions give a pretty clear indication of the concensus of opinion regarding many points of major importance relating to the curriculum.

The following numbers of individuals expressed opinions:

Graduates	6,269,	approximately 40 per cent. of those canvassed
Engineers	855,	approximately 55 per cent. of those canvassed
Teachers	534,	approximately 67 per cent. of those canvassed

The major points covered by the replies will now be discussed.

Differentiation of Curricula.—The engineers and teachers have registered their opinions on this matter by indicating whether they believe engineering curricula should be sharply, moderately, or slightly differentiated from each other. The results are as follows:

	Engineers.	Teachers.	All.
Sharply	6.2%	4.5%	5.5%
Moderately	45.6	62.5	55.1
Slightly	48.2	28.3	39.4

The verdict seems to be in favor of a moderate degree of differentiation, with a leaning toward slight rather than toward sharp. The engineers apparently desire less differentiation than do the teachers. It is significant to note in this connection that, on the average, approximately 60 per cent. of the content is common to all curricula offered by the engineering colleges.

Specialization.—The word "specialization" as here used applies to sub-divisions of the major engineering fields, whether offered as complete curricula, as curricular options, or as subjects of instruction. Such special divisions of mechanical engineering as automotive engineering, heating and ventilation, refrigeration, and the like will illustrate what is meant.

In connection with this subject, engineers and teachers were asked to state (1) whether or not special undergraduate curricula of the above character should be offered by the colleges; (2) if so, whether in all, many, or few institutions; and (3) whether the aim in teaching engineering subjects should be to prepare for particular fields of work, or whether such subjects should serve as means of teaching fundamental principles.

In general, opinion slightly favored the provision of special curricula of the type mentioned, the number of affirmatives and negatives being represented by the following percentages:

	Engineers.	Teachers.	All.
Yes	72.5%	52.1%	60.5%
No	27.5	47.9	39.5

There is general agreement, however, that such courses should be offered in comparatively few institutions, as seen from the following:

	Engineers.	Teachers.	All.
All	8.9%	11.9%	10.2%
Many	24.2	30.1	26.8
Few	66.9	58.0	63.0

There is nearly unanimous agreement that such curricula, or subjects, should serve primarily as means of teaching fundamental principles rather than to train men for particular fields of work, the division of opinion being:

	Engineers.	Teachers.	All.
"As means of teaching fundamental principles"	93.9%	93.0%	93.5%
"To train for particular fields of work"	6.1	7.0	6.5

It might, perhaps, have been assumed without question that the purpose of these special courses, as of all portions of the curriculum, is to serve as means of teaching fundamental principles. The interpretation to be placed upon the answers, in the speaker's opinion, is that these so-called "specialized" divisions (using that term for want of a better one) of the curriculum have a legitimate place in permitting the teaching of fundamental principles *through their applications.*

Fundamental Elements.—This term is intended to mean those subjects of instruction which, by reason of their fundamental nature, should be included in all major curricula. In submitting the questions on this topic to the several groups it was thought advisable to have them differ somewhat in detail, though not in substance. The questions to the teachers listed the subjects in considerable detail. Those to the engineers were more condensed. The teachers were asked to indicate by the figure 1 those subjects which they considered of *major* importance, and by the figure 2 those which they considered of *secondary* importance. The engineers were merely asked to check those which they considered should be included in all curricula. This was done since it was felt that the engineers, not having as intimate an acquaintance with the matter, would not care to record themselves in great detail. In the introduction of the question submitted to the engineers it was stated that mathematics, English, physics, chemistry and drawing were omitted from the list since there is practically unanimous agreement that these should be included in all curricula. It is therefore not possible to make a direct detailed comparison of the results, but their real substance is so clearly apparent that definite conclusions are warranted.

On the basis of the replies, considering only those subjects which the teachers considered of major importance, and giving equal weight to the opinions of the two groups—teachers and engineers—the portion of the curriculum common to all courses would be constituted as follows:

Mathematics through calculus,
General physics,
Inorganic chemistry,
Graphics—drawing and descriptive geometry,
English,
General economics,
Law of contracts (business law),
Analytic mechanics,
Mechanics of materials,
Hydraulics,
Thermodynamics,

Elements of electrical engineering,
Surveying.

In the opinion of the speaker these subjects constitute a sound, well-balanced and sufficiently comprehensive list to include all of those essential elements which should be included in the programs of all engineering students. They appear to embody a solid and coherent foundation for an engineering education.

Cultural Content.—That so-called "cultural" studies should constitute a definite part of undergraduate engineering curricula seems to be accepted as a fundamental principle by a large majority of all concerned or interested in engineering education. This is shown very clearly by the opinions expressed by graduates and teachers. Replies furnished by teachers are summarized as follows: (Percentages in this and other tables which follow are based upon numbers of answers which could be classified and not upon numbers of individuals canvassed.)

1. "Should subjects of purely cultural value be required in engineering curricula?"

Yes	78.0%	No	22.0%

2. "If so, should they be given a place of considerable, moderate or minor importance?"

Considerable	15.7%
Moderate	63.1%
Minor	22.2%

3. "Should cultural subjects be confined largely to the early years or should they be distributed throughout the curriculum?"

The former	16.5%	The latter	83.5%

In answer to a question as to the proportion of the curriculum which should be devoted to cultural subjects, the average indicated was approximately 19 per cent. The following subjects were mentioned in many replies as desirable parts of the cultural content:

Literature,
History,
Modern language,
Psychology,
Economics,
Philosophy,
Political science.

Only literature and history, however, were mentioned by a majority.

Engineering graduates hold the same views as teachers as to the desirability of including cultural subjects. All except about 14 per cent. stated that cultural studies are, in their opinion, of sufficient value to warrant their inclusion; approximately 57 per cent. rated them of ''considerable,'' or higher, importance; and over 25 per cent. stated that they believed them to be ''indispensable to their intellectual development.''

Related to the topic of cultural studies is the matter of modern foreign languages. Reference has already been made to the steady loss of ground which they have suffered. This is strikingly shown by Fig. 5, page 664, of the June, 1926, number of the JOURNAL OF ENGINEERING EDUCATION. At present considerably fewer than half of the colleges require foreign languages either for admission or for graduation; but 48 per cent. requiring them for admission, and but 32 per cent. for graduation—these figures being approximate.

Asked to give their opinions on the desirability of including modern foreign language study in the curriculum, the teachers gave the following replies:

1. ''Are modern foreign languages as now taught of sufficient value as purely cultural subjects to warrant their inclusion in engineering curricula?''

   Yes .... 26.6% No 73.4%

2. ''If your answer to the above is 'no,' please state whether you believe it is practicable so to adapt the teaching of modern languages as

to warrant their inclusion in engineering curricula as purely cultural subjects?''

Yes .... 26.9% No 73.1%

3. ''Please indicate in which, if any, of the curricula modern foreign languages as now taught should be included from the point of view of their practical or tool value?''
4. ''Please indicate in which, if any, of the curricula modern foreign languages, if given sufficient time and appropriate treatment should be included from the point of view of their practical or tool value?''

Answers to the last two questions were rather hard to interpret since less than half of the teachers expressed themselves, but it seems clear that only in the case of chemical engineering, and possibly in mining engineering is there any definite indication given of the desirability of their inclusion.

Graduates are equally clear on the matter. In answer to a question regarding subjects of the curriculum considered of the least value, they named modern foreign languages nearly twice as often as any other subject. In answer to another question, they named modern foreign languages as the division of the curriculum which should be reduced in favor of additional training in economics.

The members of the engineering societies have also registered their views on the matter, 34.5 per cent. believing that the inclusion of modern foreign languages is justified by their cultural value, and 65.5 per cent. believing that it is not. Approximately 65 per cent. stated that they had used their knowledge of foreign languages little or none in their business or professional activities.

In the words of one college president, the battle of modern languages in the engineering curriculum appears to have been fought and lost.

Economic Content.—A special committee of the Society has undertaken a study of the economic content of engineering education. The committee was asked to consider this matter because evidence gathered in other projects led to the conclusion that instruction in the principles of economics and their application to problems of engineering practice were not in as satisfactory condition as other divisions of the curriculum. Much evidence points to the conclusion that neither the type nor the extent of the economic training of engineering is commensurate with the vital importance of the economic phases of engineering work.

It would be premature at this time to treat this matter at length since the special committee still has its study in progress. It may, however, be appropriate briefly to summarize the statements of opinion which graduates, engineers and teachers have made on the subject.

Asked to state their views of the relative importance of four major divisions of the curriculum, older graduates (classes of 1919 and prior) listed them in the following order and with the relative weights indicated:

Scientific	3.4
Technical	3.2
Economic	1.6
Cultural	1.0

Asked to state their opinions as to the more important omissions from their college courses, over one half of all replies from younger graduates (classes of 1922, 1923, and 1924) cited economic, business and commercial subjects as the most serious ones. In this connection it may be pertinent to add that the engineers in expressing their opinions as to the relative ability of engineering graduates to deal with the economic elements and the technical elements of engineering problems gave the following statements:

	Recent Graduates.	Graduates of Five or More Years Experience.
"As well qualified to deal with the economic as with the technical elements"	9.4%	31.0%
Not as well qualified	90.6%	69.0%

Teachers and engineers have registered their views on the matter of the weight to be given to economic aspects of the training of engineers as indicated by replies to the following questions:

1. "Do you believe that the economic aspects of engineering deserve much, moderate, or little emphasis in engineering education?"

The replies are as follows:

	Engineers.	Teachers.
Much	49.3%	22.2%
Moderate	44.6%	70.6%
Little	6.1%	7.2%

2. "As means of giving the proper economic content and emphasis, do you favor:
   (*a*) One or more subjects given by the Department of Economics,
   (*b*) One or more subjects given by a special division concerned with the economics of engineering, or
   (*c*) Greater emphasis on the economic aspects of engineering in the engineering subjects themselves?"

The replies are as follows:

	Engineers.	Teachers.
(*a*)	26%	20.8%
(*b*)	28%	54.2%
(*c*)	62%	51.1%

There seems to be rather general agreement that more than the present emphasis on economics and its application in engineering should be given; that sufficient time is now devoted to the subject of general economics as taught by the Departments of Economics; and that it would be desirable both to provide for specific instruction in engineering economics, and to devote greater attention and emphasis to economic phases of engineering problems in the engineering subjects themselves.

Administration and Management.—It has been quite apparent in recent years that greater attention is being given to administration and management as elements in the training of engineers. Accordingly, both teachers and engineers were asked to express themselves on the desirability of including specific instruction in such matters in the curriculum. They have replied to the following questions as indicated:

"Should engineering students receive specific instruction in the realm of administration and management?"

	Engineers.	Teachers.
Yes	58.5%	58.2%
No	41.5%	41.8%

It is apparent, however, from replies to other questions, which it does not seem necessary to cite in detail, that teachers and engineers agree that instruction in these subjects and time devoted to them should not be carried to such a point as to alter the present essentially scientific and technical character of the curriculum.

Shop Courses.—A number of aspects of instruction in shop work have been considered in the various studies. Due to the difference in the nature of problems relating to shop courses when viewed from standpoints of the different branches of engineering, rather different questions dealing with this topic were submitted to the several groups. Time and space limitations do not permit of inclusion here of all of the replies. Attention will therefore be drawn only to views expressed by teachers.

Without summarizing these statements in detail, it is apparent that few teachers believe that shop work should be required of all students, but rather that shop courses should be included in curricula which relate most directly to manufacturing industries, namely, electrical and mechanical engineering. It is also clear that experience in shop work gained through summer employment should not be substituted entirely for shop work in college, though it is apparently felt that such experience might well serve as a supplement. As to the purposes of shop courses, it is clear that acquirement of knowledge of the technique of shop operations, rather than the acquirement of skill or manual dexterity, is the primary objective—this being a rather obvious conclusion. Other important, though subsidiary, purposes are evidently acquaintance with methods of shop management and knowledge of economics of shop operation.

Functional vs. Technical Divisions of Curricula.—The plan for the arrangement of engineering curricula on lines bearing a more definite relationship to the functional divisions of the work of engineers in industry, which was proposed by Professor Edward Bennett, has received much discussion and the principles upon which the proposed plan is based are so generally understood as not to require repetition. Informal discussions with practicing engineers, particularly those connected with large industrial establishments, as well as some rather careful study of the plan by the staff, led to the conclusion that the matter is of such importance as to warrant definite attention in connection with the Investigation. Opinions, pro and con, have therefore been obtained. The results follow.

After a brief but reasonably adequate explanation of the basic idea of the proposed plan, the following question was asked of engineers and teachers:

"In your opinion is there merit in the principle upon which the plan is based?"

The answers were:

	Engineers.	Teachers.
Yes	61.0%	67.8%
No	39.0%	32.2%

This was followed by the question:

"If so, is it worthy of a serious trial in one or more institutions?"

The replies were:

	Engineers.	Teachers.
Yes	69.0%	81.1%
No	31.0%	18.9%

It is evident that a very considerable body both of engineers and teachers recognize that differences in the functional activities of engineers are sufficiently distinct and important to warrant careful consideration and trial of some plan which would make possible a corresponding difference in the curriculum. An attempt to do this involves fundamental changes and readjustments which are of great importance. They demand a more thoroughgoing analysis than is practicable within the limits of this report.

Coördination of Instruction in Related Subjects.—The organic unity of structure of the engineering curriculum has been discussed earlier in this report. If the advantages which it thus affords are to be capitalized there should be close coordination of purposes and methods in teaching the various inter-related subjects. One of the criticisms most frequently made of engineering education is that such coördination is often seriously lacking. To the speaker this criticism seems to a considerable extent to be justified. It is rather natural for each of us to regard his own subject as of outstanding importance and for us to look upon its mastery as an end in itself, forgetting its relationship to other subjects and the necessity of basing our methods to a reasonable extent upon their needs. This coördination seems generally to be most needed between the basic mathematical and scientific subjects of the first two years and the engineering subjects which follow.

In view of this situation, an effort has been made to obtain a consensus of opinion first as to certain principles and second as to means whereby better coördination may be effected. These questions were submitted only to teachers. Over 80 per cent. of the replies indicated the belief that instruction in mathematics and the physical sciences should not be based upon the principle that knowledge of those subjects is primarily an end in itself, but rather that they should serve as tools in the subsequent engineering subjects. The general acceptance of this as a basic idea and the planning of methods of instruction accordingly would doubtless go a long way to make coördination more effective. It must not be assumed, however, that methods used in the fundamental subjects should be developed entirely in accordance with the views or wishes of teachers of the engineering subjects. For one thing those teachers (and the speaker is one of them) are more often prone to complain than to offer constructive suggestions. It is quite as necessary for teachers of advanced subjects to accommodate their methods to those used in the preceding ones as it is for teachers of the latter to conform to the needs of engineering subjects. Adjustment should be mutual.

As to means of effecting better coördination, the suggestion most often made in the replies is that teachers of the fundamental subjects should be engineering graduates or that they should have the engineering point of view. However desirable it might be to have mathematics and physics taught by engineers—and it is by no means clear that this is the case—it is not always possible. More definite provision for coöperation and exchange of views between departments is also mentioned by many and seems in fact to offer the greatest possibilities. More needed than anything else, probably, is general recognition of the need for coördination of purposes and methods, and acceptance of the above mentioned principle. If this is accomplished the problem is probably more than half solved.

Such, in brief, are some of the results of our endeavors to learn as nearly as possible with the means at our command the views of the interested parties in the matter of the engineering curriculum. A more complete statement of the answers of the teachers is given in an appendix to this report. The JOURNAL for December, 1925, contains statements made by graduates. The views of members of the engineering societies have been presented at this convention and will soon be available in bulletin form.

DEGREES.

This summary of the investigative stage of our undertaking would not be complete without reference to practices in conferring engineering degrees. The essential facts relating to past and present practices are given in four diagrams which will be found on pages 671 to 676 inclusive of the JOURNAL OF ENGINEERING EDUCATION for June, 1926.

These diagrams speak for themselves pretty plainly. They show a diversity of practices out of all proportion to diversity in either content, method or purposes of the curricula themselves. The records of the Society show efforts recurring at regular intervals almost from the year of its foundation to bring about a nearer approach to uniformity of practice. A majority of the colleges seem to have agreed upon the basis of the report submitted in 1910. The recommendations of that report seem to be in accordance with sound principles both as to first degrees and advanced degrees and as to the method of conferring professional degrees. While the matter of degrees is, of course, of less fundamental importance than the more vital matter of the curriculum, it would seem to justify renewed effort to bring order out of present chaos.

PRELIMINARY REPORT TO THE BOARD OF INVESTIGATION AND COÖRDINATION AND THE SOCIETY.*

BY W. E. WICKENDEN,

Director of Investigation.

The Society may be pictured as a survey party at work in the field on an important and complex job of location. We have set up and adjusted our instrument and have taken a rear sight over the path of our recent experience. Meanwhile topographic parties have been mapping the terrain just before us from the respective viewpoints of industry and the engineering profession. It is now time to turn our telescope forward, to scan the nearer foreground and the more distant horizon, and to put down here and there a stake to mark our probable route and point us toward a goal.

Our educational past, when tested by the critical judgment which engineers apply to all their works, is an honest and unpretending record. It has produced doers, not dreamers, analysts rather than artists; masters of material nature, if not humanists; and leaders of industry more often than publicists. It seems to be inherent in nature that men should have both distinctive virtues and limitations. This is the principle from which society has evolved its economic division of functions and labor. The ideal of nature and society is not the supremely versatile man, but the supremely competent man who is best able to work in harmony with other types of men. If we have produced good engineers and effective team-workers, we may stand on our record and let the critics do their worst.

We have been counselled to hitch our wagon to a star. In the present case the wagon, or to be a bit less poetic, the task, has been a study of the purposes and objects of engineering education and the fitness thereto of its curriculum; the star, or our guiding ideal, has been to "develop, broaden and enrich" engineering education. Both the wagon and the star are for the purpose of getting somewhere and not for a mere joy-ride.

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* Presented at the 34th annual meeting of the Society for the Promotion of Engineering Education at the State University of Iowa, June 16–18, 1926.

The evidence which has been set before you as the first fruits of this investigation does not point to any radical or dramatic reform. Orderly readjustments to evolutionary trends in education, industry and professional life are needed, but not revolution.

It has been the high desire of those who fostered this effort that the engineer of tomorrow may be fitted for broader responsibilities and more effective leadership. Professions owe their distinctive qualities to the type of men they enlist and the traditions with which they become invested. Men become technically proficient by being well trained, but they exercise leadership by virtue of native gifts and favoring circumstances. The engineer of tomorrow will not rise to leadership by abandoning his distinctive rôle or by permitting it to become ill-defined. He will do so by remaining essentially an engineer, by becoming a more competent engineer, by extending the reach of engineering methods and ideals to larger realms of life, and withal, by making himself a team-mate eagerly desired by other types of men. If engineering education is to serve these ends, it must safeguard all the distinctive qualities and virtues of its past and add to them a more generous humanism.

In so far as leadership depends on favoring circumstances, engineers have solid grounds for optimism. The era of a dynastic type of individual domination in industry and of political leadership in public works and services is in its wane and there is emerging a new type of administration by a professional group into which the engineer fits admirably.

In visioning the engineer of tomorrow, it seems plain that a career in independent practice will be open to only a small and diminishing minority. The consulting engineer will remain a distinguished professional type, but scarcely a normal model for the entire scheme of engineering education. The services of the profession will be more largely administrative, making the art of organizing men no less prominent than the art of controlling material nature. The services of engineers in the line or operating activities of industry bid fair to overtake their advisory or planning activities. Specialization is plainly on the increase. Few men will have occasion to practice a wide variety of engineering activities, but many will need to be expert in some one realm and intelligent in many realms.

The engineer tends to become less and less a single, distinctive professional type like the clergyman, the lawyer and the physician. His field of work tends to embrace an ever-widening range of functional and technical types of activity which call for recognition in the educational scheme. There is no well-defined threshold stage which marks off the professional in engineering from the sub-professional. In its many levels and its broad range of activities engineering can use the one-talent man, as well as the five-talent and the ten-talent man.

THE PRESENT UNBALANCE OF EDUCATIONAL FACILITIES.

That the present structure of American technical education is top-heavy and unbalanced seems plain by every test. We have concentrated by far the greater part of our facilities in degree-granting colleges, designed primarily to fit men for planning, investigative and advisory services of professional grade. We provide most meagrely for craft and trade training and for systems of apprenticeship and foreman training in industry. Training for the lesser technical positions not permanently attractive to college men is wholly inadequate. For the line, or operating type of activity, we give little distinctive training of any type.

The serious unbalance of these facilitiies leads inevitably to confusion of aims and impaired efficiency. The engineering colleges do not stand alone, but as elements in a more general structure whose defects they share. The situation is not merely bad, it is steadily growing worse through the multiplication of degree-granting colleges at the weakest end of the scale. Least defensible of all is the diversion into the already overcrowded college field of large resources intended by their donors to serve our most neglected educational ends.

This situation affects the colleges in important respects. It threatens the integrity of the engineering degree and it overloads the colleges with men for whom their distinctive type of training is inappropriate. Plainly our difficulty is not that we have too much technical education but that we have yielded to the temptation to make a fetish of the standard collegiate program and degree. The most immediate need is to provide for large numbers of young men a briefer, more practical, more intensive training than that of an engineering college, a training broader than that of a trade school, and quite distinct from that of an academic junior college. There are two types of young men to be provided for in such schools, one already employed in industry but desirous of giving a limited time to intensive technical training to facilitate his progress in chosen lines of activity, and the other the secondary school graduate who does not desire an arduous theoretical preparation, but seeks to enter the industrial field through its junior technical or supervisory services and work his way up.

There is a small group of technical institutes of non-collegiate type doing excellent work in the field described. Their graduates are able to enter active life at a fairly early age, with assured earning power, with ample time for thorough grounding in experience, and with the willingness to accept the regime and environment of operating organizations. Their records indicate that they are able to rise through the ranks to positions of considerable responsibility and that a fair number of them achieve distinguished success, though more often in the line or operating fields than in the traditionally ''professional'' fields of engineering. The present supply of of men from these sources is very small, while the demand which would certainly be created if industry undertook to adjust itself to recruitment of this kind might be expected to outrun that for college men with engineering degrees.

In every other advanced country this type of technical education is very generously provided for, and it would seem to be the complementary element most needed in our own system. Great numbers of students who enter our colleges with a valid impulse toward technical work, but without certain qualities demanded by a long and arduous theoretical training, might do themselves credit in a briefer and more practical program. With all due allowance for the college-struck attitude which prevails in our youth, it seems probable that a very much larger number of them might be directed to such a program if it were more widely provided, given suitable formal public recognition by the public and the engineering profession, and its merits set forth by adequate publicity.

It would be wholly regrettable if the present occasion, with its marshalling of the forces of the colleges, the professional organizations and the industries, should pass without constructive steps toward a better balanced program. The stake of the colleges is so great that they may well encourage this other aspect of engineering education by giving the technical institutes their moral support, by giving them a recognized place in the interests of this Society, by encouraging the professional societies to give suitable recognition to their graduates and by including this type of education in their plans for educational guidance and publicity.

The junior college is still a minor and auxiliary feature in the general scheme of engineering education, but it may become a factor to be recognized largely in the early future. It seems probable that the junior college will develop largely as an adjunct to city secondary schools and that it will give the introductory portions of standard college curricula rather than complete terminal programs, corresponding to those of the technical institutes. In time there may be a considerable development of intensive terminal courses of semi-professional nature, but if so, it will come slowly. A sound intensive course of technical training is far more expensive than ordinary academic work and needs a distinctive type of direction which few junior colleges will be able to provide.

THE UNDERGRADUATE STATUS OF THE ENGINEERING COLLEGE.

The example set by other groups of professional schools leads inevitably to the question whether the engineering colleges should follow their example, sever their connections with the secondary schools, give over to other hands the first two years of their present work, and put their programs on a strictly professional basis. As yet there are few signs of such a movement. Columbia, Dartmouth and Pennsylvania approximate this condition with their combined arts-engineering programs. Johns Hopkins has proposed to abandon freshman and sophomore work on an institution-wide basis and Stanford has a similar move under consideration. These experimental cases deserve sympathetic observation and study. A number of universities have organized on the basis of junior and senior divisions, but their engineering colleges have generally remained as integral bodies outside the scheme.

The scheme of unifying all education up to the middle of the present college program, of gradually handing it over to junior colleges and ultimately assimilating it into a more extended program of secondary education has great theoretical attractions to educationalists. It has the sanctions of European precedents and may in time prevail with us. For the present and possibly until the entire scheme of preliminary education is reconstructed, the full undergraduate status of engineering colleges seems to be a firmly fixed fact. It is one thing to share the responsibilities for the first two years with other agencies and set them a standard to which to attain, but it would be quite another to hand it over entirely.

If the junior college results only in the addition of two more years to the present type and grade of high school instruction, it may prove to be a dubious gain to engineering education. On the other hand, if it relieves the engineering colleges of any considerable part of their present burden of sifting and elimination, if it provides for many a reasonably effective program of terminal training, and if it sends on to the professional schools a well-winnowed and well-prepared group of prospects, the gains may be notable.

In California, Illinois and Michigan, where the junior college has already assumed some measure of importance as a feeder to the universities, satisfactory results have been had, although few students are fully prepared for the third year of the engineering program.

The large body of engineering colleges seem firm in their conviction that the introductory work in mathematics and science is an integral part of the engineering curriculum and apt to be best done in an engineering atmosphere. Detachment of the first two years of the present program along the lines so often urged by educationalists would be fairly certain to end in the addition of a year to the combined program, with net gains uncertain. No adequate reason has been found for insisting upon preliminary college work as a basis for admission to engineering on cultural grounds. Granted that a higher cultural ideal for engineers is greatly to be desired, it does not follow that culture must be detached from and precede professional training.

Experience seems to indicate that any plan which requires two or more years of pre-engineering study in some other college tends to alienate young men from engineering rather than attract them to it. Doubtless many should be alienated for their own good, but the impulse toward engineering appears early rather than late in adolescence and deserves a try-out before the first flush of enthusiasm is spent. To afford such a try-out is one of the first tasks of an engineering college. It is widely observed that the interest of engineering students in cultural studies is fairly feeble at the start, but that this interest rises steadily as they gain in maturity and perceive more clearly the relations of humanism to science, technology, industry and professional life.

The age at which the young engineer enters active life is an important factor in our reckoning. His training is costly. Directly and indirectly it costs society from $6,000 to $15,000 to give a high school graduate a four-year engineering course. If it is prolonged, the cost rises in even greater proportion, without assurance of corresponding gain in value. The young engineer does not enter directly upon a career of individual professional service. He has to make important personal adjustments to the requirements of large-scale organizations, and time must be allowed for a prolonged period of rudimentary experience. There is danger that a formal training protracted into mature years may result in a highly individualized and self-conscious attitude sure to prove a handicap in the initial period of readjustment.

PRE-ENGINEERING CURRICULA.

While preliminary study in an arts college seems fairly certain to remain voluntary for prospective engineering students, it may well be encouraged more widely for the sake of its personal and cultural values. If the engineering colleges wish to give such encouragement one of the most effective means may be to map out a program combining the two elements which can be covered with a reasonable economy of time. Picture the situation of an upperclassman in a high grade arts college, who is leaning toward the engineering field. If he obeys the impulse and transfers to an engineering college, his program will be to make up deficiencies in numerous introductory odds and ends of technical work, struggle with an irregular schedule and adapt himself to a method of learning involving an endless series of set tasks. On the other hand, if he completes his program in arts with credit, he may enter the graduate school of a university, probably with a scholarship or other financial aid, he may pursue a year or more of work in science, give it such technical emphasis as he can, and make his entree to industry with the prestige of a graduate degree. In the engineering college he will be a harried, irregular undergraduate. In the graduate school he will have freedom and a pleasantly individual status. Human nature being what it is, which alternative is he likely to choose and which will his college professors advise?

This seems to be the appropriate time for the Society to give special study to pre-engineering curricula. Even at the risk of some standardization, a program which could be recommended to junior colleges would be a constructive factor in their development. Likewise a suitable program for recommendation to arts colleges in conjunction with reasonably preferential terms of admission to advanced standing in engineering, so that the combination might fill five well-planned years, seems highly desirable to encourage greater recruitment of engineering from this particularly desirable source. As an additional incentive, many arts colleges might be induced to credit work in an engineering college as the equivalent of the senior year toward the arts degree in a combination plan.

At the present time a number of arts colleges offer some work in engineering toward their own B.S. degree. There seems to be no essential objection to this plan, provided such courses are designated and described so as to obviate their being confused with complete engineering curricula. It is suggested that departments, major groups and individual courses of this type should bear the designation ''engineering sciences.'' This general plan of organization seems to merit the consideration of those arts colleges of excellent standing which have maintained complete engineering curricula of merit, but which are coming to find this work a severe tax on their resources. In some cases it may be found practicable to consolidate the staff and facilities into a strong department of engineering sciences, to offer one or more group majors toward the B.S. degree, and to establish an affiliation with some strong near-by engineering college whereby graduates in such majors may complete the professional work of an undergraduate engineering program in the latter institution in a single year. Graduates of such semi-technical programs, even without the complementary year of professional work, are readily employable in engineering industries.

The Function and Scope of the Engineering College.

These preliminaries lead us to the central question—in the wide scheme of liberal, technical and professional education, what is the proper function and scope of the college of engineering? Is it a variant to the arts college, affording a somewhat different type of general education, or is it a professional school in the strict sense, like schools of divinity, law and medicine? Plainly it is an intermediate type.

A college of engineering derives its essential quality from *engineering* as a type of activity, rather than *the engineer* as a type of person. It is related to the broad economic field of public works and industry and not to the engineering profession alone. The bonds of the college to the profession are important and may well be more intimate, but the one is not merely the subsidiary of the other and properly subject to its dictation and control. If the aims of the engineering college are less restricted and definite than those of the purely professional school, they are at the same time far more definite and concrete than those of the liberal college.

For the sanction of a definition, we may turn to the walls of the library of the United Engineering Societies, where we find inscribed in letters of gold the words ''Engineering—the art of organizing and directing men and of controlling the forces and materials of nature for the benefit of the human race,'' a happy blend of the fundamentalism of Tredgold with the modernism of Stott. Usage gives to sweeping definitions of this type a more restricted sense. Engineering tradition makes the control of the forces and materials of nature the central and primary factor and subordinates to this purpose the organization and direction of men. Our definition implies that engineering has three distinctive qualities. The first is a scientific technique for the control of the forces, materials and energy of nature; the second is a technique for the organization of human effort; and the third is a technique for appraising the resulting benefits to mankind. A reasonably complete education in engineering must include these three elements. Whatever else it includes is on common terms with liberal education, to enrich personal life and fit men for a worthy place in human society.

It is the close association of training in science with its technical applications and with the means of estimating social and economic gains which marks off engineering education from scientific education in general. Such a line cannot be sharply drawn. May we be spared from the petty orthodoxy that is over-zealous about the pure and the applied. Engineering recognizes the important kindred professional fields of architecture, technical chemistry, technical biology, economic geology, technical physics and psycho-technology, without claiming jurisdiction over them. Whenever engineering can be intimately associated with these kindred interests in great schools of applied science, so much the better for engineering.

Engineering education has a common boundary with education for business which has not yet been adequately surveyed. This boundary runs through economic regions germane to both fields and still only roughly explored. The acceptance of a neutral zone between their well defined fields seems to offer the two groups the best hope of avoiding boundary wars for the present. Engineering educators, however, cannot countenance narrow and arbitrary definitions of their functions which would exclude the field of industrial operation and management from their jurisdiction, nor can they afford to yield the name ''engineering'' to courses which are wholly divorced from their control and which in no way meet the three-fold criterion of the above definition.

There is a legitimate and growing demand for an educational program which covers parts of both realms. The natural order is to place the engineering features first, since they demand a distinctive type of scientific foundation. Where distinct schools of engineering and of business exist side by side, it would seem best to segregate clearly the two portions of the program, each school having jurisdiction over the student in turn. The composite curricula now offered by certain engineering schools of the detached type fill an undeniably useful and popular place. It should be recognized, however, that they are not a substitute for engineering education proper, but rather borrow from the better established content and traditions of engineering education for the strengthening of business education.

Engineering education also shares certain common interests with agricultural education. The program of so-called ''agricultural engineering,'' with its selection of various elements of engineering associated with agricultural economy, is doubtless highly serviceable. It is not clear that agricultural engineering has developed a distinctive professional field of activity comparable to the older branches of engineering. As the curricula in agricultural engineering are now organized it is not clear that they are primarily agricultural or primarily engineering. If the former, the title seems open to question; if the latter, it is probably sound. The value of the work appears to be above question, but it may prove to be an unfortunate precedent if the engineering colleges lend their distinctive name, which they are bound to protect, to programs and policies worked out apart from their control.

To return to the center of our subject, we may repeat that a complete program of engineering education must include three characteristic techniques, one for the control of nature, one for the direction of men and one for the appraisal of values. These three elements cannot be pursued in college with equal effectiveness. There is virtually no limit to the pursuit of science, but the art of engineering leads into realms of insight and judgment for which the college offers neither background nor training. A true professional discipline deals not only with science and technique, but also with the personal attitudes, the ethical traditions and the functional responsibilities in society which give the profession its distinctive hall-mark.

Every one agrees that no college of engineering can provide a complete professional education. The collegiate features we put into a program, but the post-collegiate features we leave largely to chance. If we are to have a coherent professional training for engineering, we must bring the two stages into something approximating a unified program. There is now no single source of confusion in engineering education equal to the uncertainty as to how far the college should attempt to go, and how what it leaves undone is to be provided for.

What would help more to clarify the reasonable scope of the college program than some broad understanding on this matter between the colleges, the engineering societies and the engineering industries? If other forms of professional education have suffered from too rigid standardization at the hands of related professional bodies, engineering education may have suffered because its professional and industrial sponsors have been too aloof. If these three groups could go beyond mere definitions and actually provide jointly the means of filling the wide gaps in the larger educational scheme, especially the gaps in professional education after college, and could weld the whole into some semblance of unity, the gain might be inestimable.

Before turning our attention to the internal problems of the engineering colleges, we may recapitulate the position taken as to the scope and function of the engineering college under four heads:

1. The engineering college is not the exclusive instrumentality of engineering education. In a satisfactory scheme it would share the field with schools giving a more intensive form of technical training, and would be supplemented by means for extending professional training beyond college. The present unbalanced situation is a source of inefficiency and confusion.

2. The undergraduate status of the engineering college seems to be sound in principle and practice. Few institutions will give over to other colleges the entire pre-professional portion of their curriculum. It is desirable that there should be a closer articulation between the programs of engineering colleges, junior colleges and arts colleges.

3. Engineering colleges do not claim jurisdiction over all realms of higher technical education, but chiefly those relating to public works and industry. They assert their claim to a primary interest in the field of industrial operation and man-

agement. They undertake to protect the name engineering from indiscriminate use.

4. An engineering college cannot offer a complete professional discipline. There should be a sharing of responsibility for shaping the course of engineering education with professional and industrial bodies, and a working collaboration for closing the gaps in the present educational scheme.

PERSONNEL PROBLEMS.

In reckoning up the possibilities of betterment, they are found to fall naturally into three general groups. One relates to the general organization of engineering education, the second to the curriculum and its teaching processes, and the third to personnel. All are interrelated. The personnel problems have been largely emphasized in this study and rightly so, for they are the key to both organization and curriculum. Notable gains are unlikely unless we can attract to engineering colleges a larger quota of qualified, gifted and inspired men, both as students and teachers. There is little to add to the excellent reports already made, except by way of emphasis.

Student Personnel.—A constructive program must begin with more effective educational guidance and publicity. In presenting the nature and work of engineering to young men and their advisors, it will be necessary to use simple, vivid and concrete terms, it will be prudent to avoid all semblance of commercial solicitation, and it will be wise to emphasize the inherent idealism, challenge and difficulty of engineering no less than its appeal and opportunities. To create the background which will be needed to make the local efforts for cooperation with the secondary schools most effective, there should be a national publicity program, backed by the engineering profession in its most comprehensive sense and guided by the best obtainable publicity counsel.

We commend to the colleges as an ideal a selective standard of admission, believing that the proper intellectual demands of engineering education are more severe and its demands on occupational aptitude are more definite than those which may reasonably be applied to collegiate education in general. It seems plain that the approach to a truly selective standard of admission will be slow for many colleges, but that all will be influenced strongly by the example of effective pioneer work.

The means of selective admission actually available to the colleges are the formal entrance requirements, the methods of measuring their fulfillment, psychological tests, and personal ratings and recommendations. The natural point of attack lies in the entrance requirements and the tests of their fulfillment. This is largely a question of what the traffic will bear. In principle it seems desirable to keep the requirements in mathematics and physical sciences, both in extent and quality, as high as it is practicable to obtain, and that other required subjects be chosen for their cultural and disciplinary value rather than their occupational value. What can be had in practice is largely beyond the control of many of the colleges.

While the engineering colleges ought to use all the moral influence at their command to advance the standards of thoroughness in secondary education and to sustain curricula which afford a reasonable preparation for their work, actual steps to better the situation ought to be taken in full accord with the secondary schools. To these ends, it is recommended that the Society appoint a committee to make a detailed study of entrance requirements, the methods of evaluation to accompany them and the methods by which the desired norms of content and achievement may be set forth objectively; that representatives of the secondary schools be included in its membership; that contact be established with associations of teachers of mathematics, physics and chemistry; and that this project shall constitute one of the major projects of the Board for the coming year.

The personal adjustments associated with American college life are more swift and more crucial than those demanded of any other social group. Beginning with a sudden release from home restraints and parental guidance, they run the whole gauntlet from a new method of eating meals to a complete recasting of moral values and religious beliefs. They invest the American college with a quality scarcely known elsewhere in the world. To the student experiencing this personal revolution, the college is only incidentally a seat of learning, it is the great experiment station of youth for self-discovery and self-expression. In our wholly mobile society some such intermediate stage between the home, with its limited backgrounds and horizons, and the all-important choice of life interests, is part of the necessary machinery of democracy. All factors considered, the wonder is not that so many fail, but that so many succeed.

Our colleges can not lightly evade responsibility for sympathetic and constructive handling of these problems of personal adjustment, but it is hard to get at them by formal organization. There are inherent limits to any paternal policy. Systematic provision for services of a personal character has a fatal tendency to degenerate into an unwelcome routine. Personnel and welfare departments in industry tend to run their course and to develop into research and advisory agencies to help the regular operating forces to handle the personnel job. There are two considerations which may lead colleges to set up distinct personnel departments. One is the desire to free teachers, the operating forces in this case, from administrative detail. The other is a desire to employ a special technique such as only a professional staff can provide. It is not at all certain that teachers are bettered by being relieved of personnel duties or that students are better served by a special functional department. There is a promise of record systems which go beyond mere scholastic attainments and of a valid diagnostic and remedial technique for some of the personal crises, but these are still fields for research rather than routines. It is simple common sense to provide the Dean's office with advisory medical and psychological services for emergencies.

The serious problem of failures and eliminations which faces us is apparently an interlocking of the problem of unbalanced facilities, the admissions problem, the curriculum problem and the problem of personal adjustments. In time, we may be able to divert many to more suitable educational programs. Poor scholastic risks we shall probably be able in time to eliminate in advance, if we have the requisite moral courage. Poor moral risks, unable to meet the inherent hazards of college life, we shall always have with us. The mere fact of a student's entrance to an engineering college implies a provisional occupational choice with inherent risks. One of the student's first concerns is to prove that choice in or prove it out as the basis of his educational program. To expedite this trial we may do well to consider means of increasing the try-out values of the early part of the curriculum, the possible setting of an intermediate goal before the more specialized portion of the program is entered, and what bridges may be provided into other terminal programs.

The personal problems of upperclassmen are primarily occupational. There is probably no field of higher education in which more detailed and painstaking work is done on these problems, yet the results are far from satisfactory. The prevalent system of placement, which asks little initiative of the graduate, bewilders the man of promise by its competition, and casually ignores the man of less spectacular gifts, bids fair to break down of its own artificiality. All preferential terms which lead the graduate to assume that the employer is supposed to guarantee his future are open to serious question.

Colleges, engineers and industries can do little to better the situation radically until they are organized to deal with it jointly. The period of mal-adjustment which marks the entrance of graduates to active life is possibly the natural result of an educational scheme which aims to fit everybody to get to the top and to fit nobody to be efficient in minor responsibilities, and which ends in an undignified scramble after the stars. Lengthening the required academic program to five years or more would probably make the matter worse. If we do find a way out, we shall probably have to seek it in company with the employers, through more coöperative work, better organized summer work, a saner placement system and a more definite program and goal of further education to set before the graduate.

Teaching Personnel.—Education at its best is a form of discipleship which takes its essential quality from the Mark Hopkins who presides over the log. We have been so busy collecting the logs that Mark has had to wait. Here, surely, is the point of attack for the ''enrichment'' of engineering education.

All questions of teaching personnel lead to delicate ground. The worst that can be said of the present situation is not a matter of glaring defects, but rather of negative virtues. Statistically, the situation looks fairly sound. Inbreeding is not general; turnover is reasonable; losses to practice are moderate; major posts carrying administrative duties are reasonably well filled; and the financial rewards are rather better than those of college teachers in general. On the other side of the balance sheet we find a marked shortage of understudies for the major positions, no adequate scheme of recruitment and training, heavy loading, limited time for research and professional contacts, and an income scale which makes a sorry showing beside that of graduates in active life. The lower quarter of the two groups—teachers and graduates—have practically identical financial prospects, but the disparity at the other end of the scale is striking. There is no discount on mediocrity and little reward for high ability.

Why is it that in America an engineer who has gained some distinction in industry almost automatically declines a call to a professorship on the ground that his present work is more significant and stimulating, while in Germany he almost automatically accepts it as a step to higher responsibilities and public honor?

While there are profound differences in social status, economic situation and national temperament to be taken into account, as well as the multiplicity of professorships in one case and the rarity in the other, the fundamental difference appears to be in the type of career and the responsibilities associated with it. The problem of financial inducements is real, but it is probably secondary.

When a German is invited to a professorship, he is chosen to be primarily one of the principal agents for the advancement of his division of engineering science and art, and incidentally a teacher of youth. All illusions aside, do we not ask a teacher of engineering to be first a pedagog, second an auxiliary officer of administration and discipline, third his own combination secretary, file clerk and technician, and fourth—when there is any fourth—something of a creative factor in the realm of knowledge he professes. Granting that such a career is both honorable and useful, why should we expect it to appeal to engineers of distinguished ability?

Engineering is a type of activity concerned with tangible, measurable and contemporary achievement. These are the standards by which it measures its men and bestows its rewards. Teaching is an altruistic investment in the engineers of tomorrow and by its nature largely incapable of objective measurement and contemporary reward. It has its inherent attractions, but unless it is coupled with other forms of activity which open the way to tangible achievement and distinction, it can scarcely be expected to claim and hold the ablest men in the profession.

There are relatively few cases, and these largely in civil engineering, where the opportunity exists to combine a teaching career with one of individual professional practice. The same may be said for standing professional engagements with industrial concerns. The geographical location and working schedules of the great majority of the colleges tend to reduce such professional activities to an incidental plane. The most obvious answer is in research and kindred activities for the advancement of engineering science and art. As long as our teaching loads are as they are and all the engineering colleges combined are able to devote much less money and manpower to such activities than the investigative and development staffs of at least two single corporations, progress will be slow in investing professorships with greater prestige and drawing power through these means.

Here again we must appeal for moral and material support to the engineering profession and industries at large. We must create greater concern in these circles for the calibre of our teaching personnel and for the use of the latent creative possibilities in these colleges. Backing from these sources may go far in bringing administrative heads to recognize the inherent differences between engineering professorships and academic professorships in general and to provide financial rewards and professional opportunities accordingly.

The Curriculum.

The major problem of the investigation to which all the detail studies are subsidiary is that of the engineering curriculum. Much of the evidence has come to hand only recently and there is still more to come. Until an adequate synthesis can be made, we can deal with the subject only provisionally and in general terms.

In so controversial a field it is an advantage to begin with some point of agreement. The verdict of all parties consulted, teachers, graduates, engineers and industrialists, is definitely against specialized training for undergraduates. Moderate differentiation of programs, to enable the colleges to cultivate the field of engineering broadly and to insure enough concentration of the student's effort for good educational efficiency, is strongly supported. The traditional aim of these colleges, to train a broadly adaptable product, has been impressively vindicated. It is felt that a few colleges which enjoy peculiar advantages of location, personnel and facilities may properly provide distinctive programs for certain engineering specialites, such as sanitary engineering and ceramics, but there seems to be no valid reason for dividing the great body of undergraduate instruction into more than five or six major divisions, with moderate differentiation of group options within these major divisions.

Should the major divisions be differentiated by a technical or a functional plan of classification? The main outlines of the argument are given in the following brief:

For the technical plan:

1. Its historical sanctions.
2. Its conformity to the present organization of the profession.
3. Its conformity to the literature of engineering.
4. The availability of tested teaching materials for all major divisions.
5. The postponement to graduation of a choice between functional types of activity.

For the functional plan:

1. Its conformity to the functional organization of industry.
2. Its conformity to different types of individual aptitude.
3. More homogeneous grouping of students for differentiated educational treatment.

Against the technical plan:

1. Its non-recognition of different types of aptitude and interest.
2. The bewilderment to which it leads graduates when selecting employment.

Against the functional plan:

1. Unequal excellence of teaching personnel and material for the several functions.
2. Likelihood of grouping students according to scholastic, rather than functional, aptitudes.
3. Impracticability of detecting functional aptitudes at an early stage of the program.

It would seem that the functional scheme has distinct merits and deserves recognition in the curriculum plan, but as a secondary rather than a primary feature. We are inclined to favor preserving the framework of the present major technical curricula, and creating a bi-lateral division on functional lines in those fields which are associated with large-scale industry, particularly electrical and mechanical engineering. One side of the program might provide the more concentrated technical training suitable for the research, design, planning and advisory aspects of engineering, and the other a program of less technical concentration and suitable for the constructing, operating and commercial aspects. In general, we do not favor a distinct curriculum to give special stress to the economic and managerial aspects of engineering, which we regard as common to all the major technical divisions.

As to the normal length of the curriculum, we find no peculiar sanctity in the four-year standard. Apparently it is an academic convention we have borrowed along with our system of degrees. Its most glaring defect is its inflexibility. It is long enough to afford a reasonable general training without specialization or a narrow training with specialization. There is no evidence that a majority of the graduates find it inadequate or that they desire a longer program. Nor is the employer asking for a longer normal program. Industry is seeking a greater supply of recruits for its line or operating activities, but the specifications call for a sound general training, for strong qualities of character and personality, and for entrance to active life at an age which affords the margin of time needed for a thorough grounding in rudimentary experience.

The urge toward a longer normal program is largely idealistic. We are tempted to apply to education the principle that if some is good, more is inevitably better. Looking at the question realistically, however, in terms of costs and the needs and gifts of our students, it is not easy to justify the assumption that a longer program is warranted for the majority, on either economic or cultural grounds.

The long-standing complaint that engineering curricula suffer from overcrowding and from excessive division into fragmentary units of work is largely upheld by the evidence. It is equally clear from the experience of leading institutions, Harvard for example, that a sound general training can be given in four years' time through a relatively simple program If simplification leads to greater thoroughness, firmer and more unified grasp of fundamental concepts and relations, increased analytical power, a wider voluntary use of collateral reading, and larger zeal and capacity for self-directed educational effort, a good pruning will be profitable.

Mere cutting of requirements will not assure these results. The whole structure of subject matter needs to be closer knit. Some of the teaching methods into which we have slipped quite generally in order to maintain overcrowded schedules may need radical modification. For example, it is the pretty general testimony that engineering students devote comparatively little time to reflective study and thought, do no collateral reading and pursue no independent inquiries out of pure interest, being kept busy in grinding out innumerable, small-dimensioned, set tasks. Much of the mass that emerges at graduation appears to be the true product of this sort of industriousness, proficient in a conventional technique, but stale, unimaginative, lacking in scientific grasp and devoid of intellectual enthusiasms.

There is a good case to be made for an activity program, as distinct from a content program of education, but present indications do not point to a deliberate and rational choice between the two, but the acceptance of a task system as an expedient for getting through a large volume of work. Whatever its merits as a pure technical training, its value as a broad education and especially as a preparation for voluntary self-education is open to the gravest doubts.

A further urge toward simplification arises from the growing specialization of engineering practice. No college is called upon to turn out an all-round engineer. College training must provide the common base, with whatever distinctive foundations are needed for subsequent specialization, but the superstructure of specialized training for the most part must come with experience. Experience alone, as a basis for specialization, promises to be inadequate. What is needed is education *with* practice. The coöperative plan is a distinct step in that direction, good as far as it goes, but the parallel training is carried only through the rudimentary stages of experience and does not extend into the advanced realms of professional specialization.

The rational simplification of college programs does not call for the abandonment of any needful training, but its postponement, which means graduate work for a selected minority and definite post-scholastic education for the majority. It is a mistake to conceive of the undergraduate curriculum as a terminal program of education, or one to be completed through experience alone.

There are two distinct needs to be met in a program of post-scholastic education. One is for a broader business training than can be provided for in the curriculum, and the other is for specialized technical training to accompany experience. If such an organized stage of education is to be introduced widely, it will call for elaborate developments in extension methods of instruction. From many points of view it seems desirable that the colleges should meet this problem jointly, rather than singly. To set up an adequate system of post-scholastic training, combining business training, specialized technical training and related introductory experience, to integrate these elements into a true professional novitiate equivalent to the interneship of the physician, to relate such training to the award of professional degrees on one hand and to the terms of admission to professional grades of membership in engineering societies on the other, to make such training widely available to graduates on even terms and to make it morally obligatory upon them, would call for large-scale teamwork by the colleges, the industries and the major professional organizations. If any such development is to come, it seems eminently desirable that the initiative should come from the colleges and that they should provide in their own organization for the nucleus around which the needed organization may be created.

Parallel to the need for organized post-scholastic training is that for resident graduate work. While half the engineering colleges have graduate departments on paper, probably not more than 40 or 50 are able to provide work of adequate merit, and probably not more than 20 at the most are able to offer a wide range of graduate work of high quality. We feel convinced that nothing could be more unfortunate than a movement toward inflation. Graduate work ought to be more than an additional period of undergraduate work under a more pretentious name. At its best it is a personal discipleship, in which the student ought to seek out the best qualified master. In most cases this ought to mean a migration to some institution other than the one attended as an undergraduate. It is felt that institutions will do well to specialize and acquire a distinctive individuality in this realm of work. If these principles are intelligently guarded, we are probably safe from inflation, but if graduate work becomes a formal program to be promoted for institutional aggrandizement, it is time to hoist the danger signals.

The most obvious defect of our present general scheme of engineering education is its inflexibility, in that it affords little alternative to the standardized four-year program of an engineering college. Engineering is not a sharply defined professional field, but one of a wide range of types and levels of activity which should enlist a correspondingly wide variety of individual talents. It needs the one-talent, the five-talent and the ten-talent man. The educational scheme, however, seems to recognize and adequately to provide for only the "professional engineer."

There is a group of facts to be faced realistically and not sentimentally. Throughout the larger part of the country the engineering colleges have to carry practically the entire responsibility for higher technical education. The prospect of being able to divide the less advanced part of the field with other types of institutions is remote rather than immediate. Present circumstances bring to the engineering colleges a large body of sound human material, impelled by a fairly valid impulse to the engineering field at large, but with untried capacity for the more exacting analytical features. Many of the colleges are not free to make a discriminating initial selection from this material, and the few that are free must do so largely on scholastic grounds rather than evidences of aptitude. The result is a high ratio of elimination in course, with only a minority reaching any recognized goal of attainment through a program planned to meet their needs.

Somewhere in the course of a program of professional education for engineering an exacting standard of selection must be applied. If we are free to do it and able to do it intelligently at entrance to college, well and good, but if not then, we must apply it at some later time. If initial selection is impracticable and it is certain that many whom we admit are well able to reach an intermediate goal, is it wholly reasonable and fair to recognize only the latter? If we can recognize both the intermediate and final goal, and so add an objective of success for many without impairing the good we are able to do for the smaller number who go the whole route, is it gain or loss?

Under the conditions set forth above as premises, we are of the opinion that two alternatives are open to the colleges, one involving highly selective admission and a unitary program, and the other involving non-selective or slightly selective admission with a program divided into two or more distinct stages, thus providing both intermediate and final goals and a definite time for selective promotion to the distinctly professional stage of work after an ample try-out. It is our feeling that the latter plan has possible merits, even when measured solely by the excellence of the final product, which will fully match those of the unitary program based on highly selective admission, and that the two deserve a thorough trial, side by side.

In the present report there is not space for a detailed discussion of a suitable curriculum for each of these general plans. Recent years have seen the emergence of the junior college and the growth of a tendency to regard the mid-point of the undergraduate period as the true plane of separation between general education and university work of a professional quality. A two-stage program is consistent with these trends and fits reasonably well the present approximately equal division of the engineering curriculum into elements common to general education, and strictly technical elements peculiar to engineering. A second advantage may be found in the facility it affords for coördinating an introductory program in engineering and a terminal program in business administration or in some non-engineering technical field.

There are two distinct plans for the organization of a two-stage curriculum which merit consideration. The first is to include in the introductory stage as much general content as practicable, and only such technical content as is necessary for foundation purposes. The second is to increase the content of technical work in the first stage to include as nearly as possible all preliminaries to the higher analytical problems of engineering, and to compensate by more generous allotments of time to cultural and scientific subjects in the advanced stage of the work. The former plan has the advantage of making it easier for junior colleges and arts colleges to articulate their pre-engineering curricula with the professional stage of the engineering college. The latter plan would seem to enhance the value of the introductory stage as a try-out of engineering aptitude and as an occupational training for those who go no further.

In the introductory stage it would seem highly advantageous to adopt some scheme of sectioning students according to the excellence of their preparation and their working pace. But for the complications introduced in the non-engineering departments, it would seem advantageous to set forth the content of this stage in syllabi, rather than time or credit units, and to permit different groups to cover the ground at a different pace, without sacrifice of thoroughness on the part of any group. Presumably there would be relatively little segregation of work into distinct curricula in the introductory stage. Admission to the advanced or professional stage would presumably be highly selective, being wholly within the control of the college.

As an alternative to the usual academic program, a three-year coöperative program for the professional stage deserves consideration under favorable circumstances. Such a plan appears to be more broadly applicable than a complete co-operative plan, as it deals with highly selected student groups and involves little derangement of the educational machinery used in common by engineering and non-engineering groups of students.

Opinions as to the desirability of a two-stage plan of curriculum were sought from representative engineers, industrialists and teachers. While complete unanimity could not be expected, the first two groups expressed approval of the plan by a marked majority. Teachers were less in agreement, a few antagonistic, many sympathetic in principle, and a majority quick to point out difficulties of detail.

Irrespective of a unitary program or one divided into a sequence of stages, a change to a more distinctive professional tone and emphasis in the regime of the upper years seems highly desirable. The plan of instruction might well provide more freedom for both teachers and students, longer range assignment of work in larger units, less dependence on single textbooks and manuals as source material, more tutorial instruction, more project work of extended scale, a larger emphasis on the economic basis of engineering, and tests of the student's performance of much more comprehensive type. At this stage the student needs to be prepared for educational self-direction to be carried over into active life.

In his summary of the fact-finding work of the investigation, the Associate Director has dealt at some length with questions of the detailed content of the curriculum. Aside from excessive crowding and fragmentation, the most salient defect of content appears to relate to the economic basis of engineering. In an ideal conception of the curriculum, economics would be ranked with the physical sciences as one of the foundations of engineering. The present formal treatment of the subject does not seem to be based on such a conception, but rather that of a collateral subject of primarily cultural value. As long as this conception prevails, the provision of time for work in formal economics seems adequate, in most cases. If the treatment of the subject could be made to articulate more closely with the interests and problems of engineering, a more generous time allotment would be warranted.

Of business subjects, as such, accounting and business law seem to have the best claim for inclusion as required work. Granting that a more extended business training for engineers is much to be desired, it does not follow that it must be provided for in the college curriculum. The room for doubt as to the scientific quality and general effectiveness of much of the collegiate instruction of this character is still so great as to make it inadvisable to sacrifice scientific, technical and cultural work of well-proven value, in order to provide for it. Extended business training would seem properly to belong in a distinct program to be pursued after graduation, either in a school of business or as a form of post-scholastic training.

Greater emphasis on the economic aspects of engineering subjects proper seems clearly to be feasible and desirable. The need seems to be for only limited modifications of the factual materials in these courses, dealing specifically with costs and other economic details, but a closer association of economic and physical elements in engineering problems and in the criteria for their solution.

In the speaker's opinion, the most immediate step to be taken to qualify the engineer for larger responsibility in industry and public affairs is to increase his competency as a working economist and to win a wider recognition of this aspect of his work.

ORGANIZATION FOR FUTURE WORK.

This report has given repeated stress to the problems of engineering colleges which call for concerted action. When recapitulated, they make an imposing array. There is the problem of a better balanced system of technical education; of articulating curricula in engineering with those of other colleges; of defining an acceptable function and scope for engineering colleges; of carrying out an adequate program of educational guidance and publicity; of a selective basis of admission; of mutual coöperation with secondary schools; of providing constructively for the personal and occupational adjustments of students, and especially for a more satisfactory placement procedure; of strengthening the status of engineering teachers; of reasonable differentiation of curricula in accordance with technical and functional activities; of relief from overcrowded programs; of provision for more effective post-scholastic training and of more adequate but duly safeguarded graduate work; of the terms of award of professional degrees; of giving greater flexibility and selectivity to our program; of introducing a more distinctive professional tone to the upper years of the work; and of more adequate emphasis on the economic basis and content of engineering. I can assure you that it is limitations of time and not of material that prevent this list from being largely extended.

The conclusion seems fairly inescapable that we have already gone about as far in developing a national system of engineering education as the initiative of individuals and of isolated institutions can be expected to carry us. The present investigation has revealed a strong mood for concerted action among the colleges, provided their final autonomy is fully safeguarded. What is desired is not standardization but concerted initiative. It seems equally plain that we are faced by many problems that the colleges alone, however effectively united, can not solve, and that the colleges, the engineering societies and the engineering industries are being drawn together by the recognition of mutual problems and interests. What is wanted is effective collaboration, and not the dictation of any group to the others. Engineering education needs to be conceived and organized, not as an isolated form of educational activity, but as an integral part of the professional scheme and the industrial order.

PRELIMINARY REPORT
OF THE
BOARD OF INVESTIGATION
AND COORDINATION
NOVEMBER, 1926

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

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FOREWORD

In presenting this preliminary installment of its Report, the Board of Investigation and Coordination has in view the sequel of constructive activities to follow the work of investigation carried on during the past three years. It is the hope of the Board that this program may go forward in the colleges at once, concurrently with important joint activities by the Society with the professional engineering societies, the industries, the secondary schools and the non-engineering colleges.

The proposed program calls for the simultaneous consideration of problems of educational policy and practice by the several engineering colleges under the coordinating guidance of the Board. It is suggested that the colleges appoint committees on educational policy, with sub-committees where desirable, and that the Staff shall be at the service of these committees in an advisory capacity and as a clearing house for information.

The Board has considered certain broad questions of policy and has envisaged the wide range of educational activities in which engineering education is included, seeking to indicate its appropriate scope and character. The Report also includes a group of recommendations of more specific type, touching upon problems of general concern to all engineering colleges.

The Board recognizes that engineering education covers a wide range of activities in diverse types of institutions and must be adjusted to very uneven conditions of admission and preparatory education. The Board believes that the progress of engineering education will be best served through the freedom and initiative of the individual colleges, and deems it inappropriate to propose either measures of standardization or specific procedures for particular conditions.

I. STRUCTURE OF UNDERGRADUATE ENGINEERING CURRICULA

Fundamental Conception.—The basic process of engineering education should be an undergraduate curriculum of coherent and integral structure, directed to the grounding of the student in the principles and methods of engineering and to those elements of liberal culture which serve to fit the engineer for a worthy place in human society and to enrich his personal life. To serve its purpose adequately this undergraduate program of studies should provide a basis for the three types of activity common to all engineering, namely:

1. The control and utilization of the forces, materials and energy of nature;
2. The organization of human effort for these purposes; and
3. The estimation of costs and appraisal of values, both economic and social, involved in these activities.[1]

An educational process appropriate to these purposes can not be narrowly technical. Given a proper choice of subject matter and activity, reinforced by the incentive of purpose, the inspiration of professional ideals and the effect of a professional objective in bringing the entire process to a focus, the result of engineering education should be a sound, general development, worthy to be compared with the result of any other collegiate program. In short, good engineering education is good general education; there is no warrant for assuming that the two have different ultimate purposes which necessitate two distinct programs for the engineering student.

A Coherent Curriculum Essential.—To be sound, an engineering education must be more than the mere sum of its parts; it must be conceived and planned as a whole. While it is desirable to provide a reasonable degree of flexibility within an orderly curriculum structure through a moderate diversity of programs, some provision for the election of individual subjects and group options, and the gradual introduction of some more autonomous plan of work for selected upper-classmen, any tendency toward disintegration into a loose succession of uncoordinated subjects is to be vigorously opposed. The coherent, integral structure of the engineering curriculum at its best, with its logical sequences running from beginning to end, drawing on many fields of knowledge, but progressively bringing the student's efforts to a focus in a well-defined realm, is probably its most distinctive merit.[2]

Scholastic and Post-Scholastic Training.—The objectives of engineering education are of such extent that unlimited time might be devoted to their attainment. Money costs, the mating instinct and the time demanded for making adjustment to practical life, tend to set a time limit to education as a formal, scholastic process and to push a growing and important part of it over into the early years of productive life.[3] This principle should be frankly accepted in engineering education by recognition of the fact that the process is divided into scholastic and post-scholastic stages. A college training which prepares for entry to productive life at a normal age of from twenty-two to twenty-three is as much as can be justified for the majority of engineering students. If college training as a formal, full-time process for this majority is to be extended, this end must be accomplished through an earlier completion of preparatory studies. For the time being, limitations of the formal scholastic program must be offset by more extended provision for further training after graduation.[4] The mastery of much of the specialized knowledge and technique of engineering properly belongs to this period.

SUGGESTIONS AND RECOMMENDATIONS

A. Length and Quantitative Content.

1. The normal length of the undergraduate curriculum should remain four academic years. This proposal assumes that no attempt will be made to train men to be either spe-

cialists or all-round engineers in that period and that further training is required to fit men to engage in the more advanced engineering specialties.

2. The curriculum of four years should not, in general, require in excess of 144 credit units, measured in semester-hours, or their equivalent, exclusive of required physical and military training and required summer courses.[5] The range of from sixteen to eighteen credit-hours per week is suggested as a norm, assuming each credit-hour to represent a work load of three clock hours.

3. Six distinct subjects of instruction to be carried simultaneously are suggested as a maximum limit consistent with efficiency of effort.[6] (Closely correlated work in class and laboratory or drawing room may properly be considered a single subject.)

B. Diversity of Programs.

4. As a general practice, undergraduate curricula should be differentiated from each other to a moderate degree only.[7] As means to this end:

a. There should be an initial period, preferably of not less than a complete academic year, with a common curriculum for all engineering students;

b. There should normally be a final period, preferably of one academic year, of considerable differentiation between the several curricula, for the purpose of bringing engineering principles to a focus and of gaining the cumulative effect of narrowing the field of effort;

c. The degree of differentiation in the intervening period should fit local circumstances; it should increase progressively, but may well remain relatively small in the majority of cases, particularly between such closely related fields as mechanical and electrical engineering. (In the smaller institutions an effective plan may be worked out with only a single, final year of differentiation between civil, mechanical and electrical engineering.)

5. The primary basis of differentiation of undergraduate curricula should be the historic major divisions of the engineering profession, namely: Civil, mining and metallurgical, mechanical, electrical and chemical engineering. Differentiation according to functional types of activity, including administration and management, should be within these major divisions and should appear toward the end of the program.[8] [9]

6. Options which recognize the principal technical and functional subdivisions of the major professional fields of engineering may properly be provided in the final year of the several curricula to an extent consistent with the size and resources of the particular institution, but without pretense of giving a detailed professional training.

7. As far as practicable it is desirable that all curricula should be of equal merit and rigor, and that suitable accommodations to differences of ability should be made within each of them rather than through essentially dissimilar programs.

8. Curricula in civil, mechanical, electrical and chemical engineering may properly be offered in the majority of engineering colleges.[10] Curricula in mineral technology should be offered in only a minority of institutions. Curricula in naval architecture, architectural engineering, ceramic engineering, aeronautic engineering and similar specialties, should be offered to undergraduates in exceptional institutions only.

C. Contents and Order.

9. There should be a progressive sequence of the fundamental sciences and the related engineering principles, extending through the entire curriculum.[2] This sequence should be marked by close coordination of order, content and emphasis of the several divisions of subject matter; this coordination should not be so narrow, however, as to limit the treatment of the basic sciences to their specific uses as tools in engineering.

10. There should be a band of humanistic subjects extending throughout the curriculum.[11] [12] To increase the range of

such work available in addition to required work in English and economics, much of it may properly be on an elective basis.

11. The following subjects should be included in *all* engineering curricula, although not necessarily to the same extent:[13]

a. Mathematics, to include differential and integral calculus;
b. Inorganic chemistry, with laboratory;
c. General physics, with laboratory;
d. English composition, speech and literature;
e. General economics;
f. Introduction to the economics of engineering;
g. Introduction to the law of contracts;
h. Drawing and the principles of graphics;
i. Technical mechanics;
j. Mechanics of materials, with laboratory;
k. Introduction to hydraulics;
l. Introduction to heat power engineering, with laboratory;
m. Introduction to electrical engineering, with laboratory.

(A careful analysis, confirmed by ''A Study of Engineering Curricula,'' by Walton C. John, indicates that the time allotted to these subjects constitutes approximately two-thirds of the requirements for graduation.)

12. Modern foreign languages should not be required of all engineering students, but should be offered as electives in all curricula in which they are not required.[14] [15] (The Board holds modern foreign languages in high esteem, both as a medium of general education and as an aid to advanced study, and suggests that all engineering students, and especially those who purpose to pursue graduate work, be advised to qualify with a reading knowledge of either French or German and preferably of both; and that such knowledge

should be acquired, wherever practicable, as a part of the student's preparatory education.)

13. The order and content of the curriculum should have regard to the enlisting and stimulation of the student's interest, to his intelligent orientation to engineering activities and traditions, and to an early try-out of his aptitude for the engineering field.[16] To serve these ends, a program of concrete exercises and projects, together with suitable lectures and conferences, may be introduced advantageously at or near the beginning of each curriculum. These activities may well be supplemented by such tests as may be found to give a valid indication of the student's scholastic and occupational aptitudes.

REFERENCES

[1] For a more complete statement of this matter, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, p. 31.

[2] For an illustration in the case of the civil engineering curriculum, see "Summary of the Fact-Gathering Stages of the Investigation of Engineering Education," *Journal of Engineering Education,* September, 1926, pp. 66–70 inc.

[3] See Report as in (1); pp. 28–29.

[4] For a further discussion of this matter by the Committee on Engineering Students and Graduates, see *Bulletin No.* 3, pp. 26–29 inc.

[5] For present graduation requirements, see "A Study of Engineering Curricula," *Journal of Engineering Education,* April, 1926, pp. 517–549 inc.; May, 1926, pp. 581–601 inc.

[6] See also *A Study of Engineering Education* by Charles R. Mann, pp. 87.

[7] For a consensus of opinion in the matter, see *Bulletin No.* 9, p. 3.

[8] For a consensus of opinion in this matter, see *Bulletin No.* 9, pp. 7–8.

[9] For a more extended discussion of the plan for the functional division of curricula, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, pp. 41–42.

[10] For statistics on enrollment in various curricula, see *Bulletin,* 1925, *No.* 45, U. S. Bureau of Education, p. 13.

[11] For a consensus of opinion in this matter, see *Bulletin No.* 9, pp. 17–19 inc.

[12] For the views of a group of younger graduates, see *Bulletin No.* 8, pp. 11–12.

[13] See *Bulletin No.* 9, pp. 9–12 inc.

[14] *Ibid.,* pp. 9–12 inc.

[15] For the views of a group of younger graduates, see *Bulletin No.* 8, p. 16.

[16] For a further discussion of this problem, see *Bulletin No.* 1, pp. 23–27 inc.

II. SOCIAL AND ECONOMIC CONTENT OF ENGINEERING CURRICULA[1]

Objectives.—There are two fairly distinct objectives to be kept in view. The first is the understanding of social institutions and of the broad interplay of social forces; it is essentially philosophic and lies mainly within the educational sphere of the social scientist. The second is the capacity to deal with specific economic problems and social situations arising within the realm of engineering; it is essentially technical and is a responsibility of engineering educators.

Relations Between These Objectives.—Between these two realms of education there is as yet only a vague connection. Between *economics* and the problem of fuel *economy,* between sociology and the housing of a mining camp, there are no such detailed bonds of logic as between physics and the proper cross-section of a beam. Tangible progress in closing this gap depends equally on steps to be taken by social scientists to make their work more significant to engineers and by engineering teachers to develop more adequate methods of dealing with the technique of economy, both financial and human.

Importance to the Engineering Profession.[2]—The development of greater social insight and a larger sense of social responsibility should be a definite objective of the engineering profession if it is to gain recognition for more than its technical proficiency. At the same time it has need to improve its proficiency in dealing with problems of economy as related to the technical problems of engineering.[3] The ability of the engineer to extend his influence in industrial organizations and in public life, to claim his due share of leadership and to discharge more adequately his function in society at large, now appears to hinge primarily on his attainment of greater competency and greater recognition on the economic and social side of his work. The public has ample confidence in his ability to deal with material problems.

Place in the Curriculum.[4] [5] [6]—These considerations lend a high importance to the social sciences as an essential part of an adequate engineering education.[7] General economics is entitled to a place in all engineering curricula as a required subject. History, political science and sociology are highly desirable subjects and deserve to be included, either as required or elective subjects, wherever possible. These subjects should be taught by competent exponents and primarily for cultural rather than technical ends. These cultural ends, however, should not be left wholly vague and undefined, but should have in view the importance to the engineer of grasping the social significance of his work and of relating it effectively to other persons, social groups and social institutions.

Emphasis on Engineering Economy.[8] [9]—Considerations of social and financial economy deserve a larger place in all distinctly engineering subjects.[10] More specific attention should be given to the criteria by which the relative economy of different procedures may be judged and to the technique by which economy may be analysed. The practicability of creating a separate subject of instruction for this purpose, to be handled either by formal subject matter or by a case system of teaching, has not yet been determined. The experiences of the colleges of business administration with parallel problems are not wholly reassuring. There is an open field for experiment by engineering colleges.

SUGGESTIONS AND RECOMMENDATIONS[6]

1. General economics should be included in all engineering curricula and should preferably extend throughout a complete academic year.[11]

2. The subject of general economics should be taught by an economist of thorough competency, but with proper accommodation to the interests and view-points of engineering students. The aim should be to place economics on a plane

collateral with the mathematical and physical sciences as one of the foundation subjects of the curriculum and to create an equal degree of correlation between economics and the engineering subjects proper, in line with the recommendations of the Committee on Economic Content.

3. History, political science and sociology should be included in engineering curricula, either as required or elective matter.[12]

4. The criteria and technique of engineering economy, as related to costs, economy of design, and economy of selection and application, should be taught by engineers in connection with engineering subjects.[13] A larger emphasis on this aspect of engineering is clearly warranted.[14] [15]

5. Adequate and sustained emphasis should be given to the bearings of engineering on the broader problems of society and to the social responsibilities of the engineering profession. This end should be sought implicitly by frequent comments and allusions introduced by teachers in the regular courses of instruction. It should also be sought explicitly through subjects of tutorial instruction, supplementary lectures, articles in student publications, activities of student organizations and recommended reading. The aim should be to indoctrinate the student with a sense of social obligation which will survive pre-occupations of technical detail in his early experience and determine his attitude in the more responsible years of his maturity.

REFERENCES

[1] For a summary of present provisions in the curriculum for economics and related subjects, see *Preliminary Report of the Committee on Economic Content of Engineering Education,* presented at the annual meeting of the Society in June, 1926.

[2] See *Bulletin,* 1919, *No.* 58, and *Bulletin,* 1924, *No.* 16, U. S. Bureau of Education.

[3] For a consensus of opinion regarding the present proficiency of engineering graduates in dealing with economic problems, see *Bulletin No.* 9, pp. 12–13.

[4] For a consensus of opinion regarding provision to be made in the curriculum for economics and related subjects, see *Bulletin No.* 9, pp. 13–14.

[5] For recommendations previously presented to the Society in this matter, see *Proceedings,* Vol. XXV, pp. 225–230 inc., and Vol. XXVI, pp. 202–203, and pp. 218–225 inc.

[6] For specific recommendations, see *Report of November,* 1926, of the Committee on Economic Content of Engineering Education.

[7] For trends in relation to the place of social sciences in the curriculum, see *Journal of Engineering Education,* June, 1926, pp. 663–664.

[8] For opinions of engineering graduates of all courses, see *Bulletin No.* 3, pp. 15, 16 and 19.

[9] For opinions of a group of recent electrical engineering graduates, see *Bulletin No.* 8, pp. 13–14.

[10] For a consensus of opinions of influential engineers and engineering teachers, see *Bulletin No.* 9, pp. 13–14.

[11] For recommendation as to subjects to be included in all curricula, see Section I of this report, p. 326.

[12] For consensus of opinions of engineering teachers, see *Bulletin No.* 9, p. 11.

[13] *Ibid.,* pp. 13–14.

[14] *Ibid.,* p. 13.

[15] See *A Study of Engineering Education* by Charles R. Mann, p. 99.

III. ADMISSIONS[1]

Duty to the Engineering Profession.—The engineering colleges serve as the principal agency for the recruitment of the engineering profession and largely control its future through the qualifications and character of the students whom they attract and admit to their courses.[2] Due regard for the profession and for the industries and public which it serves calls for an educational policy designed to protect and elevate professional standards rather than to increase the number of engineering colleges; to improve the quality of student personnel rather than to expand enrollments. The pressure for more extended provision for technical education and the demand for increased technical personnel should be met for the present by the expansion of the facilities and programs of non-collegiate types of training.[3]

Admission Policies.—Policies of admission to engineering colleges should have in view the positive attraction and selection of suitable personnel. There are two immediate ends to be achieved. The first is the adoption of effectual methods of educational guidance through the cooperation of engineering teachers and leaders of the profession on one hand with secondary school teachers, parents, and other counsellors of youth on the other. The means to this end have been outlined in the report of the Committee on Students and Graduates.[4] The second end to be sought is the development and application by the engineering colleges of selective methods of admission.[5]

As stated elsewhere, engineering curricula should preserve an undergraduate status.[6] The requirements for admission to engineering colleges should accordingly be articulated with the curricula and graduation requirements of secondary schools. It is essential therefore that the colleges exert their influence to insure the inclusion in high school curricula of those subjects which are a necessary preparation for engineering study.[7] Even though the subject matter of the high school curriculum meets these conditions, the qualitative requirements for graduation in a popular system of secondary education cannot be expected to discriminate between grades of ability and types of aptitude to the extent needed in engineering education. Supplementary selective tests [8] designed to identify and admit only those who are properly qualified by endowment and preparation should therefore constitute an essential part of the normal admission procedure of engineering colleges. The evidence is conclusive that admission by certificate without supplementary selective requirements results in the admission of large numbers who are not qualified successfully to pursue an engineering program of four years' duration.[9]

Admission by examination only is a relatively exceptional practice [10] among engineering colleges at the present time and, whatever its merits, bids fair to remain so. It cannot be determined whether the advantages of the larger proportion of well qualified students and the lower elimination ratio which are associated with this practice are to be attributed to the inherent merits of the examination method or to other factors.

Admission to Advanced Standing.[11]—The conditions of admission to advanced standing which apply to graduates of junior colleges and to students who have completed all or the major part of a general curriculum in arts and sciences should be favorable to their early adjustment and progress, while guarding against the elimination or curtailment of any essential scientific or engineering subject. The conditions should be set forth as explicitly as possible and should afford a reasonable degree of elasticity in the adjustment of details.

SUGGESTIONS AND RECOMMENDATIONS

A. Educational Guidance Before Admission.

1. Literature designed to acquaint high school students with engineering and with engineering education should be

prepared by representatives of this Society in cooperation with representatives of the secondary schools. It should follow the lines laid down by the Report of the Committee on Engineering Students and Graduates.[12] It should be made available for distribution by the colleges.

2. Sections and branches of the Society may well include conferences with groups of secondary school teachers and with parent-teacher associations in their activities.

3. Addresses by engineering teachers before high school student bodies, with provision for personal interviews with students who seek them, should be arranged on the initiative of individual colleges.

B. Joint Agency of Cooperation.

4. A joint agency should be created on the initiative of this Society for cooperation with organizations of secondary schools and secondary school teachers.[13] Its activities should include steps toward educational guidance as outlined above, efforts to strengthen the status in the secondary curriculum of subjects which are an essential preparation for engineering study, joint formulation of proper entrance requirements and tests, and the development of means for the more discriminating selection of entering students.

C. Admission Procedure.[14]

5. Admission by certificate should be accompanied by more selective methods, involving any or all of the following:

a. Scholastic records in mathematics, science and English above mere passing grades;
b. A general scholastic standing in a designated fraction of the class;
c. Special recommendation of fitness by the high school principal;
d. A test of general intelligence;
e. Training and aptitude tests in specific subjects;

f. A physical and health examination to discover and provide for remediable defects and eliminate in advance those too seriously handicapped for the successful pursuit of a rigorous college program.

6. Supplementary selective tests should preferably be administered on the premises of the secondary schools immediately prior to the student's graduation. Procedures for administering the tests should be specified by the colleges and provision made for forwarding the test papers with the transcript of the student's record and the principal's recommendation.

7. Where legal or administrative difficulties prevent the formal use of selective measures to supplement admission by certificate, equivalent results should be sought through advisory measures, operating either through high school principals or by direct counsel to prospective students and their parents.

8. The practice of admitting students who are conditioned should be discontinued since this practice tends to nullify the real and potent influence a fixed standard might exert.[15]

9. The process of admission should include as an essential feature a preliminary period of orientation and adjustment to college life and engineering study.[16] One acceptable means of accomplishing this end is a period of organized activity prior to the regular program of work, generally known as freshman week.

10. To facilitate the entrance of desirable students to advanced standing and to minimize irregularities in their programs short intensive courses in such subjects as drawing, graphics, shop-work, elementary laboratory work and the like should be provided for make-up purposes and such students should be permitted, where necessary, to pursue these make-up courses in part without formal supervision.

REFERENCES

[1] For present admission practices and requirements, see *Bulletin No. 2*, pp. 22–26 inc. Also see "A Study of Engineering Curricula," *Journal of Engineering Education*, April, 1926, pp. 523–530 inc.

[2] For a more extended statement of this matter, see *Bulletin No.* 1, pp. 18–20 inc.

[3] For a further discussion of this matter, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, pp. 24–26 inc.

[4] For recommendations of the Committee on Engineering Students and Graduates in this matter, see *Bulletin No.* 1, pp. 12–18 inc.

[5] For recommendations of the Committee on Engineering Students and Graduates in this matter, see *Bulletin No.* 1, pp. 20–22 inc.

[6] See Section I of this report, p. 322; also Section VII, p. 352.

[7] For a further discussion also see *Bulletin No.* 2, pp. 6–7.

[8] For a brief discussion of aptitude and training tests, see "Iowa Placement Examinations," *Journal of Engineering Education,* October, 1925, pp. 158–163 inc.

[9] For a discussion and statistics of eliminations, see *Bulletin No.* 2, pp. 7–13 inc., and pp. 29–32 inc.

[10] For the number of institutions admitting exclusively or principally by examination, see *Bulletin No.* 2, p. 4.

[11] For a more extended discussion, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, p. 29.

[12] For recommendations of the Committee on Engineering Students and Graduates, see *Bulletin No.* 1, pp. 12–18 inc.

[13] See also Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, p. 36.

[14] For recommendations of the Committee on Engineering Students and Graduates, see *Bulletin No.* 1, pp. 18–21 inc.

[15] See *Bulletin No.* 2, pp. 5 and 26.

[16] For recommendations of the Committee on Engineering Students and Graduates, see *Bulletin No.* 1, pp. 23–26 inc.

IV. THE NON-GRADUATING STUDENT

A Problem to be Faced.—The present proportion of non-graduating students in engineering colleges is plainly excessive and indicates a negative handling of a group of important problems.[1] More positive and constructive measures are needed. There are obvious possibilities of betterment in more selective methods of admission, in improved methods of sectioning and teaching and in a type of personnel administration which seeks to determine causes as well as apply remedial measures. These remedial measures should include facilities for the transfer to other educational programs of students of good general ability who are handicapped in engineering by misdirected interest and lack of aptitude. Relaxation of graduation requirements in engineering cannot be considered, while the setting up of semi-engineering curricula of less rigor and difficulty than normal engineering programs is an expedient of very doubtful propriety. The placing of an intermediate goal in the engineering program and the restricting quite closely of admissions to the subsequent stage of work deserve special consideration.

Selective Admission.[2]—The most far-reaching remedy for the present situation is to be sought through selective admission at the outset. To gain the most constructive ends, the introduction of selective methods of admission to engineering colleges ought to be accompanied by a wide-spread provision of facilities for briefer and more intensive programs of technical education, better adapted than the present college programs to the interests, abilities and financial limitations of a large percentage of those who now seek admission to engineering colleges.[3] Until such alternative programs of technical training are adequately provided, selective admission will meet resistance and difficulty in publicly supported institutions. Unless more selective methods of admission are employed there will be a persistent temptation to make a compromise of standards between what an adequate engineering program should require and what a majority of the students actually admitted are able to do.

The Intermediate Goal.—The recognition of an intermediate goal by a certificate which may be awarded at the end of the sophomore year as a form of honorable dismissal appears to be a desirable expedient,[4] [5] especially under conditions which make selective admission impracticable for the present and in regions where non-collegiate types of technical education are now inadequately provided for. A committee of the Association of University Professors recently presented a proposal which is in harmony with this plan:[6]

> ''Every college should admit to its junior class a specified smaller number of students than it admits to its freshman class; selection should be made on a competitive basis and those who fail should be honorably dismissed with a certificate.''

The plan of selective sectioning in fundamental subjects according to ability, preparation and working pace is favorable to earnest but mediocre students and would doubtless aid many such to complete a two-year introductory program who ought not to be encouraged or even permitted to attempt more advanced work.

SUGGESTIONS AND RECOMMENDATIONS

1. A selective plan of admission, designed to check the entrance of improperly qualified students at the outset, is highly desirable.[2]

2. Encouragement and assistance should be given to the establishment and development of institutions offering briefer and more intensive programs of technical education which are better suited to many students who now enter engineering colleges and are eliminated as non-graduates.[3]

3. Students with seriously deficient preparation and those who persist in a negligent attitude, after suitable warning and counsel, should be eliminated during the freshman year.[7]

4. The plan of selective sectioning in basic subjects should be introduced for the benefit of gifted and mediocre students alike.[8]

5. Unless the plan of admission to the freshman year is highly selective, admission to the junior year should be on a selective basis.[5]

6. Students who complete two years' work with only a fair record and whose misdirected interest or lack of aptitude for engineering unfit them for the more advanced work of the upper years, should have the option of transfer to non-engineering programs or of honorable dismissal with a certificate.[6]

7. Where provision must be made for large numbers of probable non-graduates, as much of the more concrete and practical content of the curriculum should be placed in the first two years as is feasible without detriment to the preparation of those who are to continue.[9]

8. Competent personnel supervision, particularly adapted to deal constructively through diagnosis and remedial measures with cases of impending failure, should be provided wherever practicable.

REFERENCES

[1] For statistics of eliminations in engineering and other curricula, see *Bulletin No.* 2, pp. 7–11 inc., and pp. 28–32 inc.

For conclusions of the Committee on Admissions and Eliminations, see *Bulletin No.* 2, p. 17.

[2] See also Section III of this report, p. 333.

[3] For a further discussion of this matter, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, pp. 24–26 inc.

[4] See report of Committee on Engineering Students and Graduates, *Bulletin No.* 1, pp. 27–28.

[5] See Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, pp. 47–49 inc.

[6] See *School and Society* for October 23, 1926, p. 510.

[7] For the majority opinion of faculties as to the propriety of such eliminations, see *Bulletin No.* 2, p. 19.

[8] See *Bulletin of American Association of University Professors,* Vol. IX, No. 6, pp. 9–24 inc., October, 1923.

[9] See *A Study of Engineering Education* by Charles R. Mann, p. 88.

V. THE WORK OF EXCEPTIONALLY GIFTED STUDENTS

Ends to be Sought.—The Board accepts the principle of the accommodation of educational methods to individual differences.[1] [2] The principle does not admit, however, of an extreme application in engineering education where general training is blended with professional discipline.[3] The present scheme of closely supervised work in connection with an orderly plan of class and laboratory exercises is well adapted to the needs of the majority of engineering students. It is desirable to make some modification in the direction of increased student autonomy in the upper years without sacrificing the essential features and merits of this plan. Some more distinctive provision, however, should be made for the needs of exceptionally able and self-reliant students who fail to receive the maximum stimulation of their initiative and resourcefulness in closely regimented work.

The Regime for Under-Classmen.—The mental immaturity of entering students and the soft quality of much of their preparation[4] seem to make the preservation of the present strict regime of work inevitable during the first two years, if deficits in preparation are to be made good, solid foundations laid in basic subjects and mental discipline up-graded. Associated with this strict regime there should be a flexible scheme of sectioning adapted to different grades of ability.[5] The advantage conferred by selective sectioning upon the best qualified groups should be employed for the enrichment of content and the pursuit of a higher quality of achievement rather than the shortening of the period devoted to a fixed quota of work.

Autonomy for Upper-Classmen.—The present tendency is to prolong the attitude of detailed supervision and solicitude for the student's progress, which is necessary and proper in dealing with under-classmen, into the upper years. Assuming that a deliberate sifting process is to be applied at the transition from the second to the third year[6] with a view to making the upper classes reasonably homogeneous in ability, the regime of work for all upper-classmen may well be modified gradually in the direction of greater student autonomy. This result may be sought through less strict regulation of attendance, larger scale assignments of work, reduced dependence on single text-books and other consolidated sources of materials, a replacement of simplified exercises by problems and projects of substantially real magnitude and complexity, and the adoption of tests of achievement more comprehensive than those now employed. Formal classroom teaching may well be supplemented by a certain amount of semi-individual tutorial teaching.

Special Program for Selected Men.[1]—In addition to providing a reasonable increase of autonomy for all upper-classmen, as suggested above, it is desirable that more extended steps be taken to meet the needs of exceptional students who may be expected to accomplish better results by methods of semi-independent work than under the close supervision employed with the regular groups. Any highly autonomous plan of work should be introduced in engineering colleges experimentally and extended cautiously. It will require time to build up a supporting body of tradition needed for the success of the plan, to insure its acceptance by the best qualified students and the exclusion of students of a high order of routine excellence, to create the essential relationship of joint effort between the students and their faculty mentors, to develop a goal of superior excellence rather than a wider spread of effort, and to devise appropriate measures of the grade of attainment sought.

The pioneer work needed to assure the successful establishment of highly autonomous programs for exceptional students is presumably a duty to be undertaken on behalf of the whole body of engineering colleges by those institutions which have exceptional resources, facilities and freedom. The results of their experience should be given wide circulation and study among their sister colleges. For the present, the efforts of the majority of the institutions should be directed to increasing the element of autonomy and flexibility in the work of all upper-classmen, as suggested above.

SUMMARY OF SUGGESTIONS AND RECOMMENDATIONS

1. The sectioning of basic subjects pursued by large groups of students, according to ability, preparation and pace, is advised. Use should be made of this plan to enrich the content and improve the quality of the work of the best qualified groups, rather than to shorten the time to achieve a standardized end.
2. The relatively strict regime of work now in general use should be continued for all groups in the first two years.
3. A selective process of admission to the third year of the course is advised in order to insure reasonable homogeneity of ability in upper classes.
4. The plan of work in the upper years should be modified to require a greater degree of self-direction on the part of all students. This result should be accomplished for the majority by modifications in a systematic program of class and laboratory exercises, supplemented by a limited amount of tutorial instruction.
5. A highly autonomous program for selected and exceptional upper-classmen should be introduced in a few institutions specially qualified to develop the method experimentally.

REFERENCES

[1] See *Bulletin No. 52 of the National Research Council,* "Honors Courses in American Colleges and Universities," by Frank Aydelotte.

[2] See "Recognition of the Individual," by Carl E. Seashore, *Proceedings,* Vol. XXXII, pp. 111–122 inc.

[3] See "Summary of the Fact-Gathering Stages of the Investigation," *Journal of Engineering Education,* September, 1926, p. 64.

[4] For findings of the Committee on Engineering Students and Graduates relating to quality of preparation, see *Bulletin No.* 1, p. 8.

[5] See *Bulletin of the American Association of University Professors,* Vol. IX, No. 6, pp. 9–25 inc., October, 1923.

[6] See Section IV of this series, p. 336.

VI. TEACHING PERSONNEL

Need for Action.—Efforts to develop, broaden and enrich engineering education will be largely unavailing unless teaching service is able to enlist and hold able and inspiring men. The present situation, as far as statistical data can reveal it, is marked by negative virtues rather than glaring defects.[1] There is abundant evidence that increasing difficulty is being experienced in filling vacancies of the highest importance, that the more gifted younger men in teaching ranks are not being developed to the same degree as their equals in active life and that the administrative heads of institutions have not yet given the same concern to attracting and holding men of high professional distinction to chairs of engineering that has been shown in certain other realms of professional education.[2]

Prompt action should be taken to meet and offset the declining drawing power of the teaching career in engineering before a more critical situation arises.[3] Recent years have greatly multiplied the opportunities afforded in engineering practice for human service and leadership of the broader kind and for the attainment of high scientific distinction. Taken in conjunction with notably superior financial rewards, these conditions have tended to make a teaching career relatively less attractive to men of the type most desired for positions of leadership in education. A laissez-faire policy will not meet this situation.

Modes of Recruitment.—The primary mode of recruitment must clearly be the enlistment of young men for a teaching career at or near the time of their entry into active life.[4] The appointment of distinguished engineers from private or industrial practice bids fair to remain a secondary, though by no means exceptional or unimportant, mode of recruitment of the major teaching and administrative posts. Unless the rewards and attractions of these posts are such that notable men can be drawn to them from practice the ablest young men can not be induced to remain in a teaching career and advance to like responsibilities through the teaching ranks.

Development of Younger Men.—Positive measures should be taken by the colleges to insure the proper preparation and development of their younger teachers.[5] Considering the inherent handicaps to be overcome, it appears to be even more inappropriate and ineffectual for the engineering colleges to leave the professional development of their teaching personnel to the initiative of the individuals than such a policy would be in the industries. The Society, as a joint agency of the engineering colleges, should have an important share in these activities.

SUGGESTIONS AND RECOMMENDATIONS

1. Each engineering college should have a carefully worked-out policy and program for the enlistment and up-building of its teaching staff, to include definite plans for:

   a. Directing the attention of promising young men to a teaching career;
   b. Guiding prospects for teaching appointments into suitable programs of advanced study in strong graduate schools, often in other institutions;[6]
   c. Guiding prospects for teaching appointments into suitable programs of engineering experience;[7]
   d. Assisting the younger teachers to make and build up professional contacts and non-teaching activities, through association with practicing engineers, industrial organizations and professional societies;[7]
   e. Promotion of research, preferably with the direct cooperation of industries, professional societies and trade associations, as a means of development for the younger men of the teaching staffs;[8]
   f. Introducing the younger teachers to the art and science of teaching by direct instruction, individual coaching, apprenticeship, group conferences and intensive training

schools conducted by the engineering colleges in common;[6]

g. Sabbatical leaves and exchanges between institutions to increase the opportunity for travel, observation and other broadening experiences;[9]

h. Budgetary provision for making these plans operative.

2. To supplement the work of individual colleges for the up-building of their younger teachers, there should be organized activities conducted by the Society, to include:

a. Schools to be held in vacation periods for intensive training in the art and science of teaching as applied to engineering subjects;

b. Systematic joint efforts with professional societies to develop the professional standing of young teachers through committee appointments and through enlistment in the local and regional activities of engineering societies;

c. Systematic joint efforts with industrial organizations to facilitate the access of young teachers to desirable experience and other professional contacts.

3. The engineering colleges should aim to establish a scale of compensation, including economic protection and retirement features, and a plan of tenure for engineering teachers, which correspond closely to the status of engineers of like maturity and of substantial attainments in the more stable industrial organizations.[10]

4. The establishment of an economic status for engineering teachers such as that proposed in (3) above should be regarded by the colleges as a prior obligation to expansion into new fields of work and, in general, to extension of physical facilities.

5. The participation of engineering teachers in remunerative practice to a degree which augments their usefulness as teachers and educational administrators should be encouraged and should not be penalized in fixing teaching salaries.[7] Promotion, however, should not be contingent on these means

of advancing professional standing to the disadvantage of research, authorship, excellence of teaching, service to professional societies, and contributions to the advancement of educational methods.

6. Teaching loads should presuppose that the engineering teacher does not restrict his activities to instruction and incidental administrative duties, but that he is expected to be a contributor to the progress of engineering science and art. In general, the load of a teacher of maturity should not exceed fifteen hours of instruction per week.[4]

REFERENCES

[1] Summary of statistics regarding engineering teaching personnel will be found in *Bulletin No.* 4, Part III, pp. 33–45 inc.

[2] For further discussion by the Committee on Teaching Personnel, see *Bulletin No.* 4, pp. 18–19.

[3] *Ibid.,* p. 32.

[4] *Ibid.,* pp. 2–4 inc., and p. 33.

[5] For present provisions in this matter, see *Bulletin No.* 4, pp. 15–17 inc.

For conclusions and recommendations of the Committee on Teaching Personnel in the matter of the development of teachers, see *Bulletin No.* 4, pp. 27–32 inc.

[6] For recommendations of the Committee on Teaching Personnel, see *Bulletin No.* 4, pp. 30–31.

[7] *Ibid.,* pp. 28 and 29.

[8] *Ibid.,* pp. 12 and 39.

[9] *Ibid.,* pp. 15 and 29.

[10] For a full discussion of the present situation and data bearing thereon, see *Bulletin No.* 4, pp. 5–7 inc., and pp. 35–38 inc.

For recommendations of the Committee on Teaching Personnel in the matter of compensation, see *Bulletin No.* 4, pp. 21–27 inc.

[11] For present teaching loads, see *Bulletin No.* 4, pp. 7–12 inc., and pp. 38–42 inc.

For recommendations of the Committee on Teaching Personnel in the matter of teaching loads, see *Bulletin No.* 4, pp. 19–21 inc.

VII. THE SCOPE OF ENGINEERING EDUCATION

There are two quite distinct types of social needs to be considered in determining the proper scope of engineering education. One approach to the problem is from the relatively impersonal side of the types and grades of engineering services required by society; the other is from the more personal side of the types and grades of preparation needed by various groups of young men. The two approaches are not antagonistic, but there are numerous points at which the two need to be reconciled.

Types of Engineering Activity.—The recruitment and training of men for all grades of engineering activity, vocational as well as professional, call for an educational program of wider and more varied range than can be provided efficiently in a single type of institution.[1] In facing the question of what part of the entire field should be the special concern of the engineering college and what other types of institutions and courses are needed, the Board has envisaged the following types and grades of activities as falling within the engineering field, broadly conceived:

1. Engineering activities of an expert character; concerned with planning, designing, research, establishing methods, the examination of projects, and the like; commonly involving an individual or semi-individual "professional" status; and conveniently designated as "professional practice." Examples:

a. Private and consulting practice;
b. Federal, state and municipal professional service; *e.g.*, Engineer of the Coast and Geodetic Survey, Engineer of the State Board of Health, etc.;
c. Teaching and research in educational and research institutions;

d. Industrial service in a *staff* capacity concerned with *methods,* as distinct from a *line* capacity concerned with *execution; e.g.,* Designing Engineer, Research Engineer, Rate Engineer, etc.

2. Major administrative activities involving the application of engineering methods and requiring a background of technical knowledge, as well as executive ability of a more general order. Examples:

a. Major executive of an engineering industry; *e.g.,* President, Vice-President, Chief Engineer, General Manager, etc.;
b. Functional executive in a line capacity relating to production, purchasing, plant, personnel, sales, accounts, finance, and the like; *e.g.,* Manager, Superintendent, etc.;
c. Public administrative service; *e.g.,* City Manager, Highway Commissioner, etc.;
d. Private business proprietorship; *e.g.,* Jobber, Contractor, Manufacturer, etc.

3. Technical service in an auxiliary capacity; *e.g.,* Instrument Man, Draftsman, Specification Editor, Laboratory Assistant, etc.

4. Administrative service in a secondary line capacity; *e.g.,* Minor Executive, Foreman, etc.

5. Commercial service in a secondary capacity; *e.g.,* Purchasing Agent, Sales Representative, etc.

Types of Educational Service.—Limiting our consideration to graduates of secondary schools who desire preparation for activities in the engineering field, as outlined above, the Board recognizes that the following types and grades of educational service should be provided:

1. For secondary school graduates intending to devote for a period their principal efforts to further education:

a. A complete college program directed principally to a thorough grounding in the underlying sciences, the principles and methods of engineering, and the related language processes, and to the foundations of humanistic culture;

b. An extended college program in arts and sciences so coordinated with the requirements of engineering colleges that the student may transfer to the latter on advantageous terms;

c. A junior college program preparatory to the upper years of the engineering college;[2]

d. A junior college program of technical character, suitable as a terminal program;[2]

e. A thorough and intensive program of technical training, briefer, less theoretical and more specialized than the curriculum of an engineering college.

2. For secondary school graduates who are permanently employed:[3]

a. Part-time day continuation schools under the auspices of the public, the industries, or welfare organizations;

b. Evening technical schools devoted to intensive and specialized instruction;

c. A program of extension education by correspondence, principally of advanced vocational grade.

3. For permanently employed graduates of arts colleges and junior colleges and for non-graduate former students of engineering colleges:[3]

a. A program of evening studies of college grade, affording a connected development of the principles of engineering, together with collateral subjects;

b. A program of evening studies of advanced vocational grade;

c. A program of extension education by correspondence, both of college grade and advanced vocational grade.

4. For graduates of engineering colleges:[4]

a. A program of graduate work in residence, directed to more extended fundamental training and to preparation for engineering specialties of the advanced analytical type;

b. A program of resident college work concerned with the principles of administration, to supplement undergraduate courses in engineering;

c. Programs of experience and training designed to afford an orientation to particular fields of industry;

d. Programs of advanced and specialized training for particular divisions of engineering practice and industry, designed for graduates who have gained initial experience, become oriented to a definite field of effort and are beginning to assume professional responsibility;

e. A program to keep mature engineers abreast of progress and to introduce them, as needed, to advanced technical developments.[5]

It is plain that engineering is not a single grade or type of professional activity;[6] that there is no clearly defined threshold stage which separates the professional status of engineering for auxiliary vocational activities; and that engineering education should not be based on a single, idealized scheme of professional preparation, to which all schools are to be urged to conform as closely as practicable. In this respect engineering education differs radically from education for the professions of law, medicine and dentistry. In consequence methods of up-grading through imposed standardization which have been conspicuously effective in these fields are largely inapplicable to engineering education.[7]

The views of the Board as to the proper scope and character of engineering education are embodied in the following propositions:

A. Objectives.

1. The original dominating motive of engineering education was preparation for the higher forms of expert services

detailed in the foregoing outline. Henceforth preparation for the higher administrative services of engineering should take coordinate rank. It should be recognized, however, that the usual path of progress of the engineering graduate begins with subordinate technical activities.[8]

2. The same general grounding is desirable for both the technical and the administrative activities in the engineering field, since the qualities of mind and habits of thought which are the most distinctive characteristics of the engineer are of more consequence in both realms than a book knowledge of either type of technique.[9]

3. Distinctive training for both the technical and the administrative types of engineering activity should be provided, but only after an adequate grounding in science and engineering fundamentals has been laid. There should be relatively little differentiation of the two types of training in undergraduate engineering curricula.[8]

4. The auxiliary technical services and the minor supervisory and commercial activities associated with engineering are not recruited most effectively from the by-products of a program of professional training, nor are they adequately filled by using them as training assignments for men to be advanced rapidly to the higher types of engineering responsibility. These activities should be included in the objectives of a distinct, non-collegiate type of technical education, briefer, more intensive and more specialized than the programs of the engineering colleges.

B. Types of Educational Programs Needed.

1. Secondary school graduates who are qualified to profit by an extended fundamental preparation and who purpose definitely to enter the field of engineering are best served, in general, by a distinctive program of college work which includes as integral features: [9]

a. An introduction to mathematics and the physical sciences planned with reference to engineering needs and taught in connection with concrete applications;

b. An introduction to the forms of language, verbal, graphic and symbolic, which are used for the communication of facts and ideas in the realm of engineering;

c. An introduction to the social sciences, particularly economics, as related to engineering activity;

d. Appropriate elements of liberal culture;

e. An effective try-out of engineering aptitude and interest and an inculcation of engineering methods and points of view.

2. Secondary school graduates who purpose definitely to enter the technical, supervisory and commercial activities auxiliary to engineering, and who desire a specialized technical training rather than an extended fundamental grounding, are best served, in general, by a course in a technical institute or corporation school of non-collegiate type, or in a junior college organized on similar lines.

3. It is desirable that students of the type referred to in (2) above should be directed to non-collegiate technical schools wherever these are available, rather than to engineering colleges. In regions where technical institutes do not exist and where the junior colleges are not equipped to meet the need, it may be the duty of the engineering colleges to provide an intermediate technical training, either by special short curricula or by a suitably arranged introductory stage of the regular curriculum.[3]

4. Irrespective of the length of the program, the distinctive training for administrative activities which is included in engineering curricula should be:

a. Complementary and not alternative to an extended grounding in sciences and engineering principles;

b. An option which follows rather than one which parallels the introductory engineering program.[10]

5. The present agencies and programs of engineering education fail to supply an adequate recruitment for the line or operating direction of industry, as distinct from its expert

staff activities. Training for line duties requires an extended practical training gained through actual performance in industry, as well as sound educational grounding, and comparatively few men are disposed to seek such a training after graduation. The cooperative type of program has given indications of unique merit as a means of meeting this need.

C. Facilities and Standards.

1. The present group of colleges offering work for degrees in engineering is adequate numerically and sufficiently well distributed relative to population and engineering activities to meet all present requirements for the recruitment of engineering services of professional grade.[11]

2. Present facilities for the non-collegiate type of technical education are wholly inadequate for the proper recruitment of the auxiliary technical, supervisory and commercial activities associated with engineering.[11]

3. A curriculum organized on the cooperative plan, so as to combine high grade educational facilities with industrial experience which is systematically administered and subordinated to educational aims, is an acceptable alternative to the usual college program and affords in addition an adjustment of the student to the requirements of industry such as ordinarily follows after graduation. The adoption of the cooperative plan as a means of covering deficiencies of educational organization and facilities is deprecated.[12]

4. The educational standards of the present group of engineering colleges taken collectively compare favorably with those of all other equally comprehensive groups of undergraduate colleges. This statement holds for the adequacy of their physical facilities, the number and qualifications of their teachers, the level of their admission requirements, the content and rigor of their curricula, the soundness of their scholastic standards, the extent and quality of their research activities, and their expenditures per student.[13]

5. Disregarding all external comparisons and considering only variations within the group of colleges conferring de-

grees in engineering, approximately one-third of their number fall below a satisfactory standard in one or more of the above-named particulars. Institutions having such deficiencies should consider the alternative of up-grading their standards or of accepting a less ambitious status.[14]

6. In view of the present abundance of facilities for engineering education of collegiate type and the relative dearth of facilities for vocational and technical education of a shorter and more intensive type, further multiplication of engineering colleges should be discouraged for the present unless the accessions to the group are of exceptional strength. (It is disconcerting to note that most of the recent additions to the group of colleges granting degrees in engineering have had their origins under circumstances which do not afford an adequate guarantee of educational standards, being established as part of a local enterprise of educational promotion, under ecclesiastical and welfare organizations, or as purely commercial undertakings.)

7. The influence at the command of the engineering colleges and the professional societies of engineers should be employed to direct new entrants to the realm of technological education into the now inadequately filled fields of the technical institutes and the vocational schools. To this end the engineering colleges should lend their assistance and counsel in shaping suitable programs for other types of technical schools and in giving their work a recognized educational status.

D. Undergraduate Status.

1. In general it is desirable that engineering colleges should preserve their full undergraduate status. There are valid objections to the segregation of the instruction in mathematics, sciences and languages from the engineering curriculum and from the control of the engineering college, though there are also objections to the teaching of these subjects solely from the standpoint of their narrower application as tools in engineering.[15] The division of the entire program

into two parts, the first consisting of pre-engineering studies to be pursued in a college of arts and sciences, and the second consisting solely of the professional work in the engineering college, may be advantageous under exceptional circumstances but is not recommended as a general practice.

2. In general pre-engineering study in a college of arts should be voluntary rather than required, but this practice is to be commended when the student has the inclination and resources, seeks a wider range of intellectual and social contacts and wishes to defer his final decision with regard to entering engineering.[16]

3. It is desirable, however, that there should be a larger measure of recruitment of engineering colleges from arts colleges of highest standing. To this end it is desirable that there should be a closer coordination between the curricula of the two types of institutions, that the terms of admission to advanced standing in engineering colleges should be set forth as explicitly as possible, and that these terms should be as favorable to the graduates and upper-classmen of arts courses as reasonable safeguards will allow.[17]

E. Further Training of Graduates.

1. It is desirable that resident graduate work for advanced degrees should be undertaken only by engineering colleges with notable teachers and exceptional facilities; that a program of additional undergraduate studies should not be considered as graduate work leading to an advanced degree; that the several institutions engaged in graduate work should emphasize distinctive fields of effort according to their special advantages of personnel, location and equipment; that the graduate student should seek out the best qualified master in his field of special interest and, in most instances, should migrate to some institution other than the one attended as an undergraduate for the sake of the added breadth; and that financial inducements to prospective graduate students should be offered only to men of distinct promise.[4]

2. Programs of introductory experience in industry designed to serve as a process of orientation for engineering graduates meet a recognized need and deserve to be extended more widely. The aims and results of such programs, however, should not be confused with the ends sought in advanced formal training for the specialized fields of engineering practice.

3. Specialized training, other than that normally provided through the variety of quite general curricula devoted to a grounding in engineering principles and methods, properly belongs to the years after graduation. Effective training for many of the fields of individual effort in engineering can not be given efficiently in most cases before the graduate has gained sufficient experience to afford him a trial of his interests and powers and to lead him to an intelligent choice of a field of specialization. A minority of graduates may be expected to extend their formal training continuously, or after a short break, through resident graduate work.[4] It can not be assumed, however, that the majority of young engineers will normally be led to return to college as full-time students in pursuit of more advanced and specialized training. It is, therefore, necessary to provide much more fully than at present for the post-scholastic extension of engineering education of advanced character.

REFERENCES

[1] For a further discussion, see Preliminary Report of the Director, *Journal of Engineering Education*, September, 1926, pp. 24–26 inc.

[2] *Ibid.*, pp. 27–30 inc.

[3] For provisions now made by engineering colleges for these types of educational programs, see report of Committee on Services, Facilities and Costs, *Bulletin No.* 5, pp. 6–8 inc., and 18–21 inc.

[4] *Ibid.*, pp. 4–6 inc., and 15–17 inc.

[5] As illustrated by the graduate courses offered by the University of Wisconsin for practicing engineers residing in Milwaukee, see "Seminars for Practising Engineers," by Edward Bennett, *Journal of the A. I. E. E.*, October, 1926, pp. 996–998.

[6] For a further discussion, see Preliminary Report of the Director, *Journal of Engineering Education*, September, 1926, p. 24.

[7] *Ibid.*, p. 27.

[8] For opinions regarding the importance of Administration and Management as elements of the engineering curriculum, see *Bulletin No.* 9, pp. 15–17 inc.

[9] For consensus of opinion as to the common content of curricula for *all* engineering students, see *Bulletin No.* 9, pp. 8–12 inc.

[10] For consensus of opinion of prominent members of the engineering profession, see *Bulletin No.* 9, pp. 15–17 inc.

[11] This is supported by an analysis of the ratios of numbers of engineering colleges to white male population in the several states and sections of the country.

[12] For resume of data relating to cooperative engineering courses, see *Preliminary Report of Committee on Cooperative Courses,* presented at the Iowa meeting of the Society, June, 1926.

[13] For data on facilities and costs, see *Bulletin No.* 6, pp. 3–6 and 11–15 inc.

For data on admission requirements, see *Bulletin No.* 2, pp. 3–6 and 22–23 inc.

For data on curricula, see " A Study of Engineering Curricula," by Walton C. John, *Journal of Engineering Education,* April and May, 1926.

For data on qualifications of teaching personnel, see *Bulletin No.* 4, pp. 12–13 and 41–43 inc.

For data on research activities, see *Bulletin No.* 5, pp. 2–5 and 10–14 inc.

[14] This statement is based upon a careful analysis of the situation made by the Staff but as yet unpublished.

[15] For a further discussion, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, pp. 27–29 inc.

[16] For recommendations relating to the admission of such students, see Section III, " Admissions," of this report.

[17] For further consideration of this matter, see Preliminary Report of the Director, *Journal of Engineering Education,* September, 1926, p. 30.

SECOND REPORT OF THE BOARD OF INVESTIGATION AND COORDINATION

JUNE, 1927

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

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FOREWORD

This report, which will later be embodied in a report of more comprehensive character, is based upon materials which have been assembled and studies made in a general investigation " directed to a study of the objects of engineering education and the fitness of the present-day curricula," which has been conducted by the Society for the Promotion of Engineering Education. These activities have been carried out under the general direction of the Board of Investigation and Coordination and under the immediate supervision of the Staff, as named elsewhere.

In setting forth the objectives of the investigation, the Board stated its desire to clarify the educational functions and responsibilities of the colleges of engineering, by indicating the extent to which the program of engineering education serves as a *collegiate* type of training employing science and technology as its principal media; and to what extent it serves as a definite *professional* discipline; also to indicate how engineering curricula may be coordinated more effectively with the needs of industry and the requirements of engineering practice.

The present report is concerned with the objectives mentioned above and is presented as a contribution to the important problems which confront the engineering colleges. While the decisions must rest with individual institutions, the Board offers its own consensus of opinion with regard to the issues considered and expresses its views with regard to the situation as a whole.

SECOND REPORT OF THE BOARD OF INVESTIGATION AND COORDINATION

I. ENGINEERING EDUCATION—A UNIFIED VS A DIVIDED PROCESS

II. THE QUESTION OF A LONGER ENGINEERING CURRICULUM

Summary of Issues and Conclusions.*—This report deals with two distinct but related issues which now confront the colleges of engineering. The first and more fundamental is the alternative between a unified and a divided educational process; the second is the question of the normal length of the engineering curriculum.

I. A unified educational process implies a curriculum in which humanistic, scientific and technological studies are combined into an orderly whole, constituting a complete and self-contained branch of higher education under unity of supervision. A divided process implies a distinct pre-engineering curriculum under separate auspices and an engineering curriculum set up on purely technical lines, a plan corresponding to the present educational scheme in law, medicine and dentistry.

The Board is of the opinion that the engineering colleges in general may best fulfill their purpose by providing under their own auspices an educational program which is complete in itself and which may be entered direct from the secondary schools; that this type of program supplies the norm in engineering education; but that facilities should be afforded for the admission to advanced standing of students who desire a more extended general academic training before entering upon the study of engineering.

II. The issue concerning the length of the curriculum grows out of the accepted principle that more than four years of preparation are needed to equip men for creative leadership in the engineering profession. The alternative lies between a longer prescribed program, to be pursued in full or in part by all students, and a normal undergraduate program as a base with a variety of supplementary programs to fit different needs and preferences.

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* *Note:* Except where specifically noted, the term engineering education is employed in this report to denote a college program leading to a degree. It is recognized that there are other important divisions of engineering education, in its comprehensive sense, which lie beyond the scope of this discussion.

The Board is of the opinion that it is advisable to preserve the usual distinction between undergraduate and post-graduate programs and that the undergraduate program should be self-contained and lead to a degree. Opportunity should be afforded and encouragement given to students of promise to extend their formal training by means appropriate to their aptitude, ability and choice of a career, such as the voluntary election of additional humanistic studies, the pursuit of post-graduate study in a fully qualified institution, or through orderly studies pursued in conjunction with engineering experience. Four years is regarded as the normal length of the undergraduate program. In many cases this program may be divided advantageously into two stages both reasonably self-contained, and under the same supervision, in order to provide an intermediate goal and facilitate a selective process of admission to the upper years.

PART I. ENGINEERING EDUCATION—A UNIFIED VS A DIVIDED PROCESS

Purposes of Proposals to Divide the Curriculum.—Those who challenge the present status of the engineering colleges and their self-contained educational program usually propose a segregation of the program into two distinct parts, the first a general academic training under non-engineering auspices, and the second a strictly technical curriculum in engineering, comparable to those in law and medicine. This proposal is made principally by educationists on abstract grounds, but is echoed occasionally by engineers and industrialists. The intent of these proposals is to include engineering education in a general movement of somewhat various aims:

To raise the cultural level of the professions;

To sift all students to more homogeneous standards before admission to professional courses;

To postpone the final choices of departmental or professional specialization;

To make the arts college, or a similar unit, the central feature in university organization and the vestibule to all specialized instruction;

To extend secondary education, either in or outside the universities, by two years;

To professionalize the advanced instruction in all academic departments;

To transfer all general introductory instruction to junior institutions.

The critics of the present unified program of the engineering colleges seldom fail to point to the examples of a divided educational process in legal, medical, dental and theological education, and to advocate that engineering education should be organized on the same plan in order to maintain high standing as a branch of professional education.

Criticism of Assumptions Underlying the Divided Program.—The assumption is commonly made that certain subjects are inherently cultural and others are not, and that any degree of professional orientation puts a program beyond the pale of ''broad'' education. These assumptions seem to be incidental to narrowly conventional definitions of culture. The engineer would maintain that culture cannot be restricted to the fine arts and personal graces, however desirable for the enrichment of life, but must be conceived equally in terms of insight into the social bearings of one's calling, qualifications for efficient team-work with men of other callings, and the ability to invest one's work with large social values. Culture, so conceived, ought not to be divorced from professional preparation. Granting that the present means to these ends in the engineering curriculum may be greatly improved, it does not follow that they would be bettered through dissociation, but rather that the cultural possibilities inherent in engineering education should be more fully explored and developed.

Another assumption is that it would be profitable to extend the student's preparatory education by one or two years, and that more valid choices of specialization would result. European examples are often cited in support of this position, but the fact that this higher scholastic level is normally reached abroad at the age of eighteen is often overlooked. The age level and stage of mental maturity mark a more significant threshold to professionally oriented studies for the engineering student than the level of scholastic attainment. The urge to prepare for a technological career normally appears at or before eighteen, rather than later. It is necessary to employ these natural enthusiasms of the student as incentives for a long and arduous formal training under the rising pressure of his instinctive urge to do, to create, to deal with tangible and realistic situations, to achieve economic independence, and to mate at a normal age. Furthermore, as a student, his time is subject to a law of diminishing returns, and a balance must be struck between formal education and training through actual experience.

What the engineering student needs at the outset is not so much a widening of his intellectual horizons as a discipline in more intensive and directed methods of mental work; the broadening process is much more effective if distributed over the entire educational program. Experience indicates that a faulty perspective of cultural values on the part of the student is more readily corrected by sympathetic guidance in an engineering college with adequate provision for humanistic studies in the later years of its curriculum, than by consigning him to a probationary period in an arts college.

A further assumption is that the engineering colleges would profit greatly by a preliminary sifting of their students. Doubtless they would if the sifting process were based on a valid trial of interest, aptitude and ability. However, the actual results of a divided program, in which another type of college is made to serve as a vestibule to engineering, have been seriously disappointing; it appears that the spark of enthusiasm for engineering is quenched more often than it is kindled and that more students are diverted from engineering through prejudicial influences than are directed to it through constructive educational guidance. This result is reflected in a marked shrinkage of enrollments and graduations in engineering under the divided plan without indications of compensatory gains in the qualifications of graduates, when comparisons are made between educational programs of equal total length. The unified engineering program, on the other hand, offers tangible means of try-out and guidance to the student with tentative engineering objectives, and exacts little penalty of the student who transfers to another educational program within a reasonable period.

Are Precedents in Education for Other Professions Relevant?—Technical training for the profession of law, medicine, dentistry and, to a less degree, the religious ministry, is distinctly set off from the processes of general education and all the first-class schools preparing for these professions require from two to four years of general college work for entrance. The accentuated professional status of these schools and the long formal training in two stages are often upheld as examples to the engineering colleges. It is fitting to point out, however, that there are few if any parallels involved, apart from the common use of the term ''profession.''

First, there is striking dissimilarity of historical backgrounds. Education for law, medicine and dentistry had its origin in a system of pupillage or apprenticeship, out of which there developed an extensive system of private proprietary schools of strictly technical character. When these schools were later assimilated to a university status they preserved their separate identity through a sharp division of the educational process into pre-professional and professional stages and in many cases established themselves on separate premises. In contrast, the type of engineering education which developed in American colleges has been from its origin an inclusive educational process, instituted and directed by professional educators, conforming to university standards, and more academic than vocational in type. While originating in distinct polytechnic schools of university grade, it early gained recognition and place in institutions of the broadest academic character and has held and extended this position during a period of eighty years.

The early curriculum in American colleges of engineering was conceived as an alternative and a challenge to the traditional classical discipline. Unlike the strictly professional disciplines mentioned above, engineering education has never been under the exclusive domination of a professional group; non-engineers have shared equally with engineers in shaping its character and destiny. It is significant that early engineering curricula contained little of the technique of engineering practice, but emphasized an objective approach to the physical sciences with a view to the economic use of materials and sources of power in nature, as contrasted with a subjective concern with the organization of systems of scientific knowledge. The science of engineering, rather than the art, has consistently dominated the engineering curriculum and even to this day the materials for a complete discipline for the practice of engineering have never been developed in systematic form.

Second, the professions concerned are of dissimilar nature. Law, medicine, dentistry, and the religious ministry are strictly defined professions, based on a single level of responsibility and largely concerned with a service by individuals to individuals. Each has a distinctive social and legal status, and the first three have monopolistic rights and privileges under the law, which make restrictions as to entrance a necessary protective measure for society. The auxiliary or subprofessional services related to these professions are in the hands of distinct groups and there are no open promotional routes from group to group. These conditions tend to fix the forms of professional education in a series of standard patterns. In contrast, engineering—concerned with the economic use of materials and energy—is one of the very general functions in social economy, and not the exclusive function of a well-defined professional group. It has many levels of responsibility and no clear distinction has ever been drawn between the professional and the auxiliary levels. The profession of engineering is self-constituted and traditionally open and inclusive in its organization. Promotional routes run through all grades of responsibility and legal restrictions as to entrance are relatively nominal.

Third, the professions concerned have different relations to educational practice and policy. Law, medicine and dentistry are represented by strong central organizations, able to formulate and largely able to impose a strict educational policy in connection with legal restrictions on entrance to professional standing. Within the last twenty years each of these professional bodies has had occasion to take strong protective measures in the face of a common problem, namely the flooding of the profession with the poorly educated and meagerly trained graduates of low-grade schools operated for profit. It was urgently necessary to raise the qualifying levels of general education, up-grade the standards of technical training, bring the schools under university auspices, impose proper limitations of numbers and introduce selective processes to guarantee suitable personal qualifications of recruits. The chief means chosen to these ends has been the prescribing of two years or more of college work as a prerequisite of admission to highly specialized professional curricula. The engineering colleges, on the other hand, have been almost wholly under university standards and educational auspices. The elements of general education included in engineering curricula have long been equivalent to those now prescribed for admission to all but a few exceptional schools of law and medicine. There is no centralized body in the engineering profession which could formulate and enforce a strict educational policy. Engineering enrollments have been relatively stationary for many years and there has been no flooding of the profession by an excess of recruits. In short, there has been no need of drastic reform in engineering education to protect or advance the interests of the profession, but only of healthy evolution. The profession has never undertaken to bring the educational process under its direction or control.

Fourth, the division of an educational program implies that its professional stage is designed exclusively to fit students for definite professional careers. This is not the sole purpose of engineering education. As previously stated, engineering is actually one of the most general functions in social economy, and not exclusively a form of professional service.

There would be no conceivable gain to society in making scientific technology the monopoly of a restricted professional group, as in medicine and law, nor is there any inherent basis for limitation of numbers in technological education. On the contrary, there is positive social gain in the wide diffusion of men with engineering training throughout the entire range of industrial, commercial and public activity. The professional element in engineering education, which gives it characteristic form and direction and marks it off definitely from a loosely grouped body of scientific studies, is of great value, but the undergraduate program is conceived not so much as a specific professional discipline as a professionally oriented form of education. It is significant that engineering training qualifies graduates to function in the whole range of directive responsibility in industry and public works; less than one-third remain permanently in predominantly technical work and less than one-tenth establish themselves in an individual professional capacity. Present tendencies relative to curricula, teaching processes, personnel practices, student activities and the enrichment of institutional life in the engineering colleges are in marked contrast to the practices of the strictly professional schools of law, medicine and dentistry, and testify to the ideal of serving the student as an individual rather than fitting him into a pre-determined professional mold.

Present Status of the Engineering Colleges.—There are now more than one hundred and sixty colleges in the United States and Canada which offer complete engineering curricula leading to degrees. With two exceptions, Dartmouth and Columbia, these schools are all organized as undergraduate colleges, with or without associated post-graduate departments. Only four institutions in all have organized their curricula in two distinct stages under separate direction. There are nineteen polytechnic institutes such as Rensselaer and Massachusetts Institute, and seven colleges of mines as Colorado (Golden) and Missouri (Rolla) which are devoted primarily to technological curricula and research and are committed by tradition and circumstances to an integral educational process. Forty-nine of the engineering colleges are included in the Land-Grant system established by the Morrill Act of 1862 with the intent of providing a liberal type of technical education which should be widely accessible to the industrial classes and should aid in investing industrial pursuits with a professional quality. The Land-Grant colleges have unquestionably been a powerful influence tending to hold engineering education to its original ideal of a unified educational process. Forty-two other institutions, exemplified by Lafayette and Swarthmore, are colleges devoted largely or exclusively to undergraduate studies and without distinct professional schools. Fifty-three engineering colleges, or slightly less than one-third of the total, are included in institutions with a university type of organization which provides for separate professional schools.

Considerations of Educational Efficiency.—The following summary touches briefly on many of the more specific aspects of the problem:

1. *Preparatory Education.*—The present tendency in the high schools is to sacrifice the type of intellectual formation requisite for rigorous analytical studies to a process of so-called enrichment and socialization of curricula. The engineering colleges now exert a corrective influence through distinctive entrance requirements which would inevitably disappear if these colleges should lose direct touch with the high schools and act through the arts colleges as intermediaries. The result would be the loss of one or more years of valuable time to the student, and a certain diminution of the quota of students qualified to enter upon engineering studies.

2. *Motivation.*—One of the marked values of the unified program, entered directly from the secondary schools, is that it capitalizes the student's natural motivation. To keep the student longer away from studies which bear on his life purposes tends to prolong a juvenile attitude toward education at a time when he needs to learn the method of intensive, directed effort.

3. *Scientific Grounding.*—Mathematics and physical sciences are an organic part of the engineering curriculum and

not mere formal prerequisites to be "passed off." The building up of these foundations in an unbroken sequence is one of the most essential conditions of effective engineering education. There is need for a more thorough mastery of these subjects and for greater facility in their use as tools than are considered requisite for college students in general. The engineering student, as a type, learns principles best in conjunction with their applications, a condition which would not obtain in the divided program.

4. *Sequences of Studies.*—Effective sequence of essential scientific and technological studies requires four consecutive years; it does not occupy them fully, however, and affords time for a parallel sequence of humanistic studies, which gain from the student's advancing maturity and add to his insight into the broader social implications of technology. In the divided curriculum cultural studies lose in significance through being dissociated, and technological studies are likely to be crowded into a sequence too brief for the best results.

5. *Adaptation of Program to Varying Needs.*—Programs of engineering education of varying length and character are needed to fit different requirements. For the present, it may be impracticable to set apart different types of institutions to serve these several ends, and the engineering colleges may need to approximate to them by a program of adjustable length. The unified plan, with humanistic, scientific and technological studies distributed through the curriculum in continuous sequences, lends itself to these purposes.

6. *Time Economy.*—The advantages of time economy are all on the side of the unified program, which affords greater assurance of close articulation of preparatory studies and college work and of purposeful and intensive effort than can be expected in a non-engineering college. Unless a pre-engineering curriculum is given over very largely to scientific preparation, at least five years in all will be required to accomplish the present ends.

7. *Advanced Studies.*—The unified program affords a clear distinction between undergraduate and post-graduate work. The divided program, however, requires a longer period to

accomplish the same ends, thereby tending to confuse deferred undergraduate studies with real advanced work and lessening the margin of time and the incentive to pursue it. When undergraduate and advanced studies are clearly separated, there is greater probability that students will seek out special centers of advanced work for the sake of exceptional facilities, a condition that deserves to be encouraged.

8. *Educational Demand.*—There is a large and wholly legitimate demand for technological education of moderate length and exactions. It is important to strengthen and extend the base of technological education through larger development of a system of training of high quality but of intensive character aiming at fairly immediate utility, such as is now provided by a small group of non-collegiate schools. It is important to stabilize on the undergraduate level a considerable majority of the present engineering colleges founded to make and keep technical education accessible to the great body of the public. Failure to do so will lend encouragement to proprietary schools of dubious quality and to institutions which subordinate intellectual ideals to welfare motives.

9. *Transition of Graduates to Active Life.*—Experience indicates clearly that it is bad for morale to delay too long the adjustment to practical life or to make the transition from a highly intellectual type of college program to a necessarily rudimentary experience too violent. There is a definite possibility of keeping many promising men too long in college. These considerations apply with less force to men entering upon an individual professional status or work of a research character, but engineering colleges cannot limit themselves to such groups. To do so would break contact with the normal operating functions of industry and public works, from which most of the increase of demand for graduates bids fair to come.

Summary of Argument.—The unified plan of engineering education has valid historical sanctions, is firmly fixed in status, and is consistent with the objectives of the engineering colleges; it makes the most of the student's motivation, aids in the try-out of his educational and professional choices, and lends itself to adjustments of program to fit individual needs;

it fits into the requirements of the public and industry and makes for time economy; it exercises a wholesome influence on secondary education and insures the requisite sequence of studies; and it subtracts nothing vital from the cultural ideals of education, but affords opportunity for a closer linking up of cultural and vocational interests. The circumstances which led to the adoption of the divided plan in other branches of professional training are almost wholly lacking in the case of engineering. A general abandonment of the present unified program would be a disrupting influence in educational organization and would have little support from the engineering profession. There has been no demonstration of the superiority of the divided plan on either cultural or technical grounds, when programs of equal total length are compared; and no convincing case has been made for its general adoption.

Defense of engineering education as a unified process should not be mistaken as a plea for uniformity. There is no inherent reason why all engineering colleges should be organized on the same plan or offer similar programs of studies. Standardized uniformity is sterile, but diversity makes for progress which is more often spread through experiment and example than imposed through mass movements. A comparison of engineering curricula of the unified type with present curricula in medicine and dentistry indicates that the engineering colleges enjoy greater freedom from standardization. Local circumstances may make a division between the engineering curriculum and the introductory general studies advantageous in particular institutions and it is well that the plan should be fully tried out. The actual trials thus far made have not achieved assured success and the more notable advances of recent years have been achieved in institutions which maintain a unified program.

PART II. THE QUESTION OF A LONGER ENGINEERING CURRICULUM

Past and Present Experience.—The four-year undergraduate engineering curriculum has been the dominant type of program in the American engineering colleges for eighty years.

Efforts to establish longer regular programs have been made at intervals by a number of institutions of prominence, but have either been given up or have persisted with precarious success. Among the institutions which have tried and discarded longer curricula are Harvard, which maintained for eight years a Graduate School of Applied Science, Missouri, Wisconsin, California, and Minnesota. With the exception of certain special cases * there are but three institutions at present which actually maintain programs of more than four years as their principal practice. Dartmouth and Columbia admit the student to the engineering college after three years of work in arts, and credit one year in engineering toward the arts degree. The course in engineering proper is three years in Columbia and two in Dartmouth, and leads in both cases to the degree of ''Engineer.'' Columbia, however, now offers an alternative plan whereby the degree of B.S. may be gained in four years and one summer. Northwestern gives its entire program of five years under the direction of the engineering college and awards the B.S. degree at the end of the fourth year, so that its practice differs only nominally from that of the eighty-one institutions which offer advanced work for graduates on an optional basis. There is therefore but one institution, *i.e.*, Dartmouth, other than certain cooperative schools, where the first degree in engineering cannot be gained in a four-year period, and that institution has enrolled of late but ten to twelve engineering students per year.

Seventeen institutions have definitely scheduled combined courses in arts and engineering of more than four years' duration, offered as an alternative to the regular undergraduate engineering program. In a number of cases combined programs are set up through an affiliation of two institutions. The proportion of students enrolled under this plan is relatively small. A considerable number of students voluntarily enter engineering colleges on advance standing from arts colleges, without a formal articulation of curricula, and many engineering colleges encourage this type of extended program.

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* Eleven institutions have cooperative undergraduate programs extending over more than four years. Four colleges have a five-year program in one department and four-year programs in all others. One offers five-year programs for the degree of ''Engineer'' paralleling its four-year programs for the bachelor's degree.

Aims of Longer Curricula.—The efforts to establish longer required programs have aimed principally to advance the standards of engineering education on its humanistic and scientific sides, rather than to extend the technical instruction to a more advanced level, except in graduate schools. The institutions concerned have acted individually; no concerted effort to introduce a longer curriculum as a general practice has yet been attempted. The nearest approach to such action was taken by representatives of fourteen mid-western institutions in 1922, and set forth in the following resolution:

> "In order to meet the constantly enlarging responsibilities of the engineering profession, we favor an advance in engineering education at this time that shall provide five years of collegiate training for those engineering students whose aim is to become qualified to take positions as the creative leaders in the profession, and that such advance shall be made in substantial accordance with the following plan:
>
> "1. Include in the four-year engineering curricula a substantial proportion of fundamental and humanistic subjects, omitting if necessary a sufficient amount of the more advanced technical work. It is desirable that, as far as possible, the curricula in the different branches of engineering shall be sufficiently uniform to permit students to defer their final choice of a specialty at least to the end of the second year.
>
> "2. Add a fifth year of advanced work, mostly or wholly technical, and specialized to such an extent as desired.
>
> "3. The first four years of work shall lead to a bachelor's degree and the fifth year to an advanced degree in engineering."

Advanced Studies.—As stated above a large proportion of the engineering colleges offer advanced work following the completion of the regular undergraduate program. Almost without exception these institutions regard their four-year programs as normal and the fifth year as a period of postgraduate study. In some of these institutions, and notably in a few, the number of graduate students has been increasing steadily. There were almost exactly 1000 graduate students of engineering enrolled in American colleges in 1924–25. This number is between ten and twelve per cent of the total of first degrees in engineering awarded at the end of the preceding academic year. Sixteen institutions awarded a total of 572 graduate degrees in engineering in 1924–25. Since that time the number of graduate students of engineering has increased appreciably. More than three-fourths of the present graduate enrollment is in ten institutions, pointing to a tendency to migrate to the stronger schools for special advantages at this stage.

Difficulties with Longer Curricula.—It has been the general experience that longer formal curricula have lacked the drawing power needed to insure a satisfactory numerical success; they have not attracted adequate groups of students in competition with normal undergraduate curricula in the same institutions or in others of equal rank. While these efforts have been made by distinguished institutions, there has been no instance where the superiority of teaching personnel or physical facilities associated with a longer curriculum has been so marked as to be the determining influence in the result. Moreover, it does not appear that efforts were made to assure strong moral or material backing for these experiments from the engineering professions and industries. Had these conditions been met, the outcome might have been different, but the fact remains that longer curricula have not succeeded in gaining a firm position on the strength of inherent superiority as an educational process.

There is a widespread desire among educators to provide a superior preparation, beyond the possibilities of a four-year curriculum, for students who give promise of developing into leaders of engineering and industry, but there appears to be little demand for a longer scholastic program for the average student. Many of the proposals for longer formal programs are assumed to have a selective basis; they are intended to apply to students of superior ability or to institutions of a distinguished character. Difficulties arise, however, when attempting to make such a segregation by formal means.

The tangible gains in providing a more extended training for selected men have been achieved largely on a voluntary basis and in institutions which maintain the normal subdivision between undergraduate and post-graduate work. This gain has been made in about equal measure through the combining of courses in arts and in engineering on the student's own initiative, and through an increasing tendency to pursue post-graduate work. The admirable educational programs for graduates which have been developed by certain progressive industrial concerns have become important contributions to more extended education for selected men. The present tendency to associate these advanced courses in industry more closely with the graduate schools of the universities is a factor of large promise. These voluntary measures appear to be more successfully selective than any formal prescription for longer training, and to afford greater flexibility in fitting the educational program to individual needs.

Policy Suggested.—In the judgment of the Board an undergraduate program does not constitute in itself an adequate preparation for many of the higher forms of engineering activity, but it embodies the foundation subjects which constitute the essential basis of engineering education for the great body of students. Up to a certain point, it is both necessary and advantageous to organize the curriculum in a limited number of divisions which aim primarily at group needs; beyond that point it is essential that training should be highly diversified to meet the needs of individuals and of engineering requirements. The Board considers that the undergraduate program is as extended as can be given to good advantage to considerable groups of students and that further training should be largely diversified in length, type and setting. Furthermore, there is a need for many institutions to give thorough undergraduate instruction, but a relatively limited number of institutions with specialized facilities are needed for more advanced work. It would be wholly unfortunate to invite many substantial undergraduate institutions to inflate their programs, by setting up the standard of a five or six year engineering curriculum as a measure of educational respectability and standing.

When all factors in the situation are considered, it seems desirable to recognize the distinction between undergraduate and post-graduate work in engineering as normal, to encourage many institutions to offer the former and relatively fewer the latter type of instruction, to plan the undergraduate curriculum so that it may serve as a terminal program for the average student, to make an extension of this program optional with the student, and to encourage the student of promise to extend his formal training, either through the voluntary election of additional courses in humanistic subjects before or during the engineering curriculum, or through post-graduate study in a fully qualified institution, or through orderly part-time studies in connection with engineering experience. The commonest exceptions to the normal four-year program will occur in cooperative courses, where the undergraduate curriculum is spread over a longer period, and in programs which combine two distinct curricula, such as arts and engineering, engineering and business administration, and the like.

Undergraduate Curricula.—In accepting the four-year undergraduate program as a norm and a more extended program as optional, certain principles deserve to be recognized and stated:

1. The four-year curriculum should constitute an acceptable terminal program for the large body of students who wish a general engineering training, and properly leads to a bachelor's degree. In many cases the undergraduate engineering program may be divided advantageously into two stages, each reasonably self-contained, in order to provide an intermediate goal and to facilitate selective admission to the upper stage.

2. Students registered in the undergraduate engineering curriculum should have the privilege of extending the program to five years by the election of additional humanistic and scientific subjects, preferably in the later years of the course.

3. Since a four-year program provides primarily a general foundation training for engineering, a high degree of differentiation of undergraduate curricula by technical or functional specialties is inadvisable. A primary differentiation according to the major branches of the engineering profession, supplemented by group options in the fourth year, is considered appropriate. There should be little or no differentiation in the first year, and a final choice within groups of

closely related curricula should remain open to the end of the second year.

4. A longer undergraduate curriculum may be offered appropriately for students of good general promise who are handicapped by incomplete mathematical and scientific preparation, especially where the engineering colleges are obligated by their public relations to admit such students. In such cases the longer curriculum is supplementary and not a normal program; it does not aim at a higher level of attainment and leads to the bachelor's degree.

Post-Graduate Work.—The Board advises that students who are well above the average in general ability and who purpose to become qualified for creative engineering work should extend their studies through one or more graduate years, leading to a higher degree. Such a program should be decided upon in the upper years of the undergraduate period rather than at its beginning. This additional work may well take one of three forms:

1. An orderly curriculum of advanced studies in engineering technique or administration, in any engineering college well staffed and equipped for engineering instruction on a high professional level.

2. An elective resident program of advanced scientific studies and research in a graduate school; this type of program is appropriate only where notable staff and facilities are provided in both engineering and scientific departments.

3. A program of advanced professional study partly or wholly under industrial auspices, but preferably with organized cooperation between the industry and a graduate school of high rank.

It is advised that a considerable number of the present engineering colleges confine their efforts to a sound undergraduate program and pursue the practice of directing their graduates to other institutions for advanced work.

CONCLUSION

In conclusion, it seems fitting to outline the Board's conception of the place and function of the engineering colleges in the educational scheme and to indicate some of its ideals for their future progress.

It is the Board's belief that engineering education is so broad in its aims and that its methods are so truly educative as fully to justify its established position as one of the major complete branches of higher education. The engineering college is conceived to be coordinate in organization and status with the college of liberal arts, in both undergraduate and post-graduate divisions. There is a clear-cut distinction, however, in their purposes and their methods of work, which invests the engineering colleges with a professional character. The undergraduate engineering curriculum properly combines humanistic, scientific and technological studies into a coherent and integral program which is set off from a loose grouping of scientific studies by a well-marked professional orientation. The professional element in the curriculum becomes increasingly important in the upper years of the program and dominates the more specialized work of the post-graduate years.

The Board recognizes the need to develop, broaden and enrich engineering education, in view of the constantly enlarging responsibilities of engineers in society and the increasing exactions of professional practice. It holds, however, that this development should proceed from within, by enhancing the distinctive qualities of engineering education, rather than by adding to it unrelated elements from without; that the preservation of a unified program better lends itself to this end; that it is desirable to give a more generous place to distinctly humanistic studies in the curriculum and to give these studies a form and content * which will enrich the student's conception of engineering and its place in social economy; that it is desirable to give the student a more connected and better

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* It is the expectation that the Board will deal with the form and content of the humanistic studies of the engineering curriculum in a later section of its reports.

grounding in engineering principles; that a greater effort should be made to develop the student's capacity for self-directed work; and that these ends should be gained, wherever need be, at the expense of unrelated studies on one hand and of detailed technical training on the other. The Board holds that detailed training in engineering technique should be more adequately provided for in both post-graduate and post-scholastic courses.

The Board holds that the principal efforts for the improvement of engineering education must take the direction of a simpler and better balanced curriculum, better selection of students, better qualified teachers, better teaching methods, better subject matters and more adequate provision for advanced training, rather than changes in the scheme of educational organization.

THIRD REPORT OF THE BOARD OF INVESTIGATION AND COORDINATION, JUNE, 1929

Prefatory Note.—In view of the fact that the studies under the Board's direction will not be completed until the end of the present summer, the present Report may be considered as an extension of the two installments already published. It deals primarily with matters of concern to the degree-granting colleges. When the report on the more intensive forms of higher technical education has been completed it is the intention to publish a synthesis of the entire group of investigations, consolidating the preliminary and final Reports with the supporting evidence published in the Bulletins. The present Report has been prepared by the Staff of the investigation, has been reviewed by the Board, and is published with its general approval.

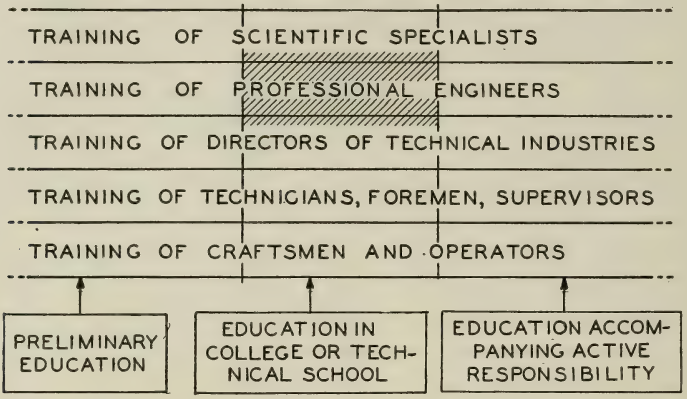
Technical Education in the National Educational System

Our Lack of a National Policy.—It is plain that technical education has grown up sporadically in America and has never been thought out as a whole. The experience of the more mature nations abroad indicates that it is quite possible to go wrong under either a bureaucratic or a *laissez faire* policy with profound effects on national destiny. France showed remarkable early fertility in technical education and held undisputed leadership up to 1850. Then followed forty years of arrested development; the State held a monopoly of higher education under the bureaucratic system but took no effective initiative; local and private initiative finally took up the burden, but only after the late War did the State resume its responsibility for a balanced and adequate development. Meanwhile the early supremacy had been irretrievably lost with far-reaching effect on French industrial development.

Great Britain, on the contrary, lost fifty years of her early industrial lead over Germany and the United States by leaving all technical education to local and private initiative under an extreme *laissez faire* policy. Britain was equally slow to perceive that a specially selected and trained personnel was needed to apply science to industry effectively. Nearly a century of her effort was concentrated on the incidental education of workingmen, while technical education in the universities was nearly stifled by neglect. It has taken forty years of intensive effort to redress the balance. Technical education in Germany, after being thrown out of the older universities by conservative educators, was taken up and fostered by far-seeing statesmen bent on transforming a group of backward agricultural states into a powerful industrial empire. Nowhere else have technical education and research so largely shaped national destiny. After 1860 it was increasingly clear that while the states and the industries were supplying the motive power of technical education, it was the engineering profession working with educational leaders which was guiding the movement out of its early confusion into a well-ordered scheme.

In the United States the pioneer efforts of Gardiner and van Rensselaer, and of their proteges Hale and Eaton, "to promote the application of science to the common purposes of life" quickly solidified into one special form, that of a professional discipline for engineers. This, in turn, was quickly assimilated into the collegiate branch of the educational system which at that time was just taking on an orderly form. Engineering education was already firmly established when the engineering profession became an organized body. In consequence of this early fixation, technical education has had a vigorous development in only one compartment of our educational system. It has developed independently, without guidance by the profession or effective bonds with industry. Its aims have been largely individualistic. The early definiteness of aim has been impaired by the effort to make a single type of school cover the entire range of educational needs. Meanwhile inadequate provision has been made for large sections of our youth in need of technical preparation and industry has been given an unbalanced recruitment.

The Field of Technical Education Inadequately Covered.—The fact that the engineering colleges can cover only part of the broad area of technical education, and that not a wholly independent part, needs to be more clearly recognized. Representing the area of education for technical pursuits by horizontal bands to denote its several functions and by vertical bands to denote successive stages of training, we have this figure:


TRAINING OF SCIENTIFIC SPECIALISTS
TRAINING OF PROFESSIONAL ENGINEERS
TRAINING OF DIRECTORS OF TECHNICAL INDUSTRIES
TRAINING OF TECHNICIANS, FOREMEN, SUPERVISORS
TRAINING OF CRAFTSMEN AND OPERATORS
PRELIMINARY EDUCATION
EDUCATION IN COLLEGE OR TECHNICAL SCHOOL
EDUCATION ACCOMPANYING ACTIVE RESPONSIBILITY

The shaded area represents the primary concerns of our engineering colleges. It is a small part of the whole. What can be done within it depends intimately on what comes before and what goes after, also on what is done or not done in the collateral areas. If we consider the possible betterments in the single band which represents the professional training of engineers, probably less than half can be considered apart from preparatory education or after-college training. The possible betterments within our control are important, of course, and well worth our best efforts, but they are only a minor part of what needs to be done to make technical education an effective arm of our national social and economic organization.

We are convinced that our engineering colleges will never attain to their highest effectiveness until they are included in a more comprehensive system of technical education, planned with reference to national as well as individual needs. It is important to get some concerted national thinking on this matter. We can not look to a central government to lead us; industry lacks suitable organization and a constructive policy; the engineering profession is not awake to the problem; our educators and colleges are wrapped up in their own local problems and special interests; this Society is not in itself a sufficiently representative agency. It is, however, the best nucleus we have to start with. It is imperative that we should continue to urge this issue on the technical professions, the industries and the public authorities and seek to prepare the way for some joint representative agency, such as the German Committee on Technical Education created on the initiative of the *Verein Deutscher Ingenieure* with the cooperation of other professional, industrial and educational bodies.

The Selective Principle in Engineering Education

Selective Aims and Functions for Schools.—There is a need for clear thinking on the primary aims of the schools of engineering—whether to prepare young men for fairly definite pursuits, or to aid in the development of their individual talents of whatever nature. The former conception makes for selectivity, the latter for comprehensiveness. Within certain limits the two aims are reconcilable; beyond these limits they tend to become divergent and finally opposed. Engineering is a relatively diverse rather than narrowly specialized realm of activity and the area of mutual adjustment between the two aims is fairly wide. It is plain to all that the ideal of comprehensiveness rather than selection has taken almost complete possession of public secondary education. The issue between the two ideals is now being contested in higher education and a fairly strong movement exists to establish in the undergraduate period, and especially in the first two years, much the same conception of aim as now prevails among the secondary schools, namely that of social guidance and exploratory processes rather than a clearly directed training. There is a counter movement toward much greater selectivity during the entire college period. This issue is of particular concern to the engineering colleges, since they, more than any other group of undergraduate schools, are committed to a definitely functional type of education and one which is essentially continuous in certain of its elements with the preparatory education which precedes it.

We are strongly of the opinion that engineering education should be a selective process. In the wider sense this implies a selection of distinct spheres of work by different types of technical schools, rather than conformity to a common pattern; it implies a selection of schools by students and of students by schools according to different aims and functions;

and it implies selective treatment of students to accord with different types of interest and levels of ability.

We are convinced in principle that it is desirable to maintain distinct types of schools to prepare men for the higher intellectual functions and for the higher practical functions of industry and of engineering; these aims we regard as of equal worth; yet we recognize that in a free society this process of selection actually goes on in many cases within the school or in after life, rather than at or before admission. We deem it desirable that there should be a wide variety of higher technical education, varying in the length and intensiveness of its programs and in the relative degree of scientific and of practical emphasis. It seems futile to us to set up an abstract ideal of the ''best engineering education'' and to seek to impose it on all schools and all students. The result would be only an unsatisfactory compromise between equally worthy but divergent ideals, making our present one-sided situation worse rather than better.

We would encourage, therefore, a wider development of types of school which frankly undertake to prepare men for the higher practical functions of industry, schools which teach technical applications in a very direct manner and technical sciences as auxiliaries to that end. By singleness of purpose it is possible for these schools to develop a distinctive type of teaching material and method, not a mere abridgment of conventional college matter and process, of the highest educational merit. In general these schools should be able to give a highly effective training in less than four years. Excellent examples, both in America and abroad, fully sustain this position.

To an equal degree we would encourage a group of institutions which have both freedom and resources to concentrate on the higher intellectual aspects of engineering, both in undergraduate and postgraduate studies, to a considerably greater extent than at present. We fully recognize the difficulties in the way of any large degree of differentiation between existing colleges and we expect the majority to hold to a middle-of-the-road policy between service ideals and intellectual standards, yet we are convinced that the well-being of all is dependent on the existence of at least a few institutions which are uncompromising in their devotion to creative intellectual effort.

The Principle of Selection in the Curriculum.—As a premise, we reaffirm our belief in a unitary process of engineering education which begins at the present age levels and combines cultural, scientific and technical disciplines into a closely coordinated whole. While definitely professional in orientation, the engineering curriculum ought not to be narrowly technical in matter or spirit, but should have in view the social functions of engineering no less than its tools and technics. Imperative limitations of time, however, make it essential to apply clear and rigorous principles of selection:

1. Differentiation of Curriculum.—A common curriculum for all engineering undergraduates appeals to many as a method of confining attention to "fundamentals." While it is probably advantageous to have certain institutions of compact size and selective aims follow this plan, we are not convinced that it is best for general use; instead we favor the principle of progressive concentration. We deem it desirable that the student should be led to bring his diffused aims to a focus and that a gradually increasing differentiation of programs makes for that end. Our primary concern should not be with content, but with mastery of the methods of learning and we believe a cumulative effort to be of greater worth than of ever widening spread. We favor increased concentration on fundamentals but the range of sciences basic to engineering—mathematics, physics, chemistry, geology, biology, economics, physiology and psychology—is too wide to permit any individual to deal thoroughly with all. The same is true of the technical sciences—mechanics, thermodynamics, electrodynamics, hydraulics, metallurgy and the like—and even more true of the technical applications. A single curriculum for all would simply exclude large areas of engineering science from the colleges, a condition which we would deplore. Some reasonable plan of selection by related groups seems both necessary and desirable. Many student bodies are too large for effective supervision as a unit. The tutorial system never has succeeded with large groups of engineering students; on the other hand dividing them into pre-professional groups has worked well, on the whole, in appealing to student enthusiasm, in creating a bond of mutual interest between teachers and students, and in creating helpful contacts with professional and industrial organizations. It is also of the highest importance that teachers shall have the opportunity to pursue individual forms of effort, leading to professional contact and recognition.

To restate our earlier position, we believe that the largest group of advantages, under ordinary conditions, may be secured through progressive concentration of effort in three stages: (1) an undifferentiated period of at least one year; (2) a period of moderate differentiation centering on basic groups of sciences such as physics and mechanics, physics and electrodynamics, physics and chemistry, physics, chemistry and geology, etc., which underlie the major branches of engineering; and (3) a final period of greater concentration in group options which aim at a cumulative rather than a scattering result. While this plan has been followed in a liberal spirit, emphasizing the learning process rather than specialization of content, the graduate has not been found wanting in adaptability.

2. *Humanistic Studies.*—In the choice of humanistic studies we hold that the primary criterion is not one of intrinsic cultural or intellectual values, nor one of narrow utility, but that of functional relation to engineering. English studies, both for facility of expression in speech and writing and for acquaintance with literature, studies which deal with the evolution and present state of social processes and institutions, studies in human nature and conduct, studies in economics both social and technical, and modern languages for tool and colloquial uses, are to be regarded as integral elements in engineering education, rather than as preliminaries or addenda. We recognize, however, that it is not practicable to provide instruction in all of these branches for all students. Unless the levels of preparatory education are exceptional, we deem it essential to include instruction in English and in economics in all engineering curricula. Furthermore, we favor an unremitting insistence on clearness and accuracy of expression in all work, written or spoken, performed by engineering students, and think it proper for the colleges to deny graduation to students whose daily work does not bespeak a

relatively high standard of literacy. In our opinion, the lack of acquaintance with historical backgrounds is a handicap to the progress of the technical professions; we therefore commend to our colleges a more general study and teaching of science and technics as molding forces in civilization. Beyond the requirement of English and economics, we feel that the choice of other humanistic studies should be governed by local conditions and special needs, keeping always in view their functional relation to engineering pursuits. If a margin of time remains after this criterion has been fully met, we favor keeping it free for studies having purely cultural aims.

3. *Scientific Studies.*—A like principle of selection and emphasis on functional values applies to the mathematical, physical and natural sciences. Sound knowledge of mathematics, to and including calculus, and of physics and chemistry, we hold to be indispensable in all cases, but the teaching of these branches as distinct entities must be justified through economy of learning and thoroughness of mastery of fundamental relations and processes rather than on abstract or traditional grounds. In general, we favor teaching these subjects departmentally, but with a definite functional emphasis on their engineering uses, and with engineering students in distinct groups. In such rapidly expanding sciences as physics and chemistry, we deem it necessary to introduce in some measure matters which as yet lie beyond the range of engineering application. Where time for this purpose can not be provided in the fundamental course required of all students, we believe that elective advanced courses should be offered as alternatives to some course or courses in technical application. The biological and geological sciences, for the present, must be taught selectively to those groups of students who require foundation courses for their technical branches, but it seems desirable to provide wider opportunities for elective studies for other groups, in view of the growing importance of organic as distinct from mechanical conceptions of nature and society.

It is scarcely possible in our judgment to overstress the importance of thorough grounding in mathematics, physics and mechanics, and the close integration of these subjects. We consider it highly desirable that mechanics should be begun as early as practicable. The advisability of separating the introductory course from the course in general physics has not been studied critically. This practice prevails universally in Great Britain and seems to contribute to the notable thoroughness achieved there in the teaching of engineering mechanics. While we are not prepared to make any definite recommendation, we would suggest that this matter be taken under advisement and experiment. In case such an introductory course in mechanics is introduced, we suggest that the head of the course act as a liaison officer, responsible for developing a close coordination of mathematics, physics, drawing and mechanics.

4. Technical and Administrative Studies.—The vast expansion of engineering knowledge has compelled the schools to choose between an extended treatment of the general technical sciences—mechanics, thermodynamics, electrodynamics, and the like—with a limited treatment of applications, and, as an alternative, a strictly utilitarian treatment of these sciences and a fairly extended consideration of their applications. The problem is further complicated by an insistent demand for the recognition of a wider range of engineering functions in our college programs The day is definitely past when we may limit our teaching to the purely physical side of engineering; the economic and the human aspects must be given their due place. We are convinced that the primary lines of division between curricula, for both theoretical and practical reasons should follow the major divisions of the engineering profession. We feel, however, that the range of engineering sciences and functions within each professional division and the differences in individual talent and interest are becoming too wide to be accommodated within a single program of studies.

We know of no solution of this problem which fits all schools and circumstances; as stated before, we favor diversity rather than uniformity of schools and programs. As one experimental approach, we would suggest a trial of bilateral options in the major professional curricula, one to emphasize the dominantly scientific and technical phases of engineering, and the other the dominantly economic and human phases. The detailed working out of such a plan must be left to trial and experience. In principle, we believe that the more technical option should give the primary place to the basic technical sciences, rather than their detailed application; we therefore favor the inclusion of mechanics, mechanics of materials, thermodynamics, electrodynamics and hydraulics in all of these more scientific options, though in varying degrees appropriate to the major professional fields. While we do not favor teaching these sciences in an abstract or disembodied form, but with ample illustration of their applications, we advise against a primary effort to make the student proficient in particular skills and technics of supposedly practical value in engineering practice. One of the major objects in proposing a definitely scientific option is a much greater thoroughness of grasp of the fundamental sciences on the part of students who may be expected to do creative technical work in engineering. The prevailing standard we believe to be far too low.

An optional side of the curriculum emphasizing the economic and human phases of engineering can be dealt with only tentatively in the present state of experience. That the efforts to solve this problem by creating distinct courses in industrial engineering and engineering administration have served a useful purpose is sustained by abundant testimony. We believe, however, that a broader solution must be sought within the several professional curricula. It would seem, however, that we have not yet developed a mature engineering science that goes far beyond the practical expedients of management. What has been done lies almost wholly in the realm of mechanical engineering; little or nothing has yet been attempted educationally in the realms of civil, electrical, chemical, mining or metallurgical engineering, although there is a considerable literature of the problems of engineering and human economy in these areas available for use in management options. There is manifestly a minimum level of scientific and technical studies below which no curriculum can properly be called a course in engineering. It would be unwise to approach near to this limit by an excessive substitution of economic and administrative studies in their present state of development. Furthermore, the testimony of graduates in engineering administration to the value of the older engineering sciences in developing rigorous, analytical habits of thinking is impressive.

Certainly mathematics, physics, chemistry, engineering drawing, mechanics, mechanics of materials and at least one and preferably two other of the more general technical sciences should be retained, as well as a fair consideration of their applications. In the aggregate, perhaps one-sixth to one-quarter of the entire time might properly be given to studies of engineering economy and administration as such. We would point out, however, that creating such options in the major curricula does not remove the need for greater emphasis on the criteria of engineering economy in the more technical branches. In the time specially devoted to administrative studies, due attention should be given to industrial organization and finance, to cost analysis, to accounting in its more scientific aspects, to industrial personnel and to the interrelations of engineering and the economics of production and distribution. We would emphasize, however, that the successful teaching of these matters can be developed only in the hands of men who have had extended and responsible industrial experience. The technical sciences can be taught with fair success by relatively inexperienced men with the aid of good text-books and laboratories; not so matters of engineering economy and administration. We would deprecate any wide multiplication of text-book courses given by men of scant first-hand qualifications. Unless this work has distinctive engineering qualities, it would seem rather to belong to the sphere of the colleges of business.

In this connection we would reaffirm our view that the proper time for specialization is after the undergraduate course, and that in a majority of cases specialization must accompany active experience rather than take the form of a further discipline in college. The provision of effective continuation education for this period remains one of our most urgent problems. We commend the action of the Committee on Education of the American Institute of Electrical Engineers in taking this matter up for active study; we also commend as examples the combined courses of practical and theoretical training which have been set up jointly by certain electrical industries and graduate schools; and we would encourage other institutions to experiment with means for the further education of graduates in this period.

Selection in the Treatment of Students.—We reaffirm our view that admission to engineering colleges should be selective, both for aptitude and scholastic qualifications. We note with interest and approval the increasing efforts of research to identify the aptitudes which have peculiar significance for engineering and to find practical means to measure and appraise them. We urge the engineering colleges to a larger share in this effort. Wherever conditions will admit, we favor raising the minimum level of scholastic qualifications for entrance to engineering colleges. In a few cases the present requirements appear to be too inflexible, in many others distinctly loose. We propose, in general, a higher qualitative standard, but we do not favor raising the normal age level of entrance as a means to this end. There are minimum levels of preparation in mathematics and science, as well as in general literacy, below which a satisfactory college course in engineering can not be completed in the present four-year period We recognize that many institutions of a regional character have an obligation to articulate their requirements with the actual state of secondary education in their areas. Where satisfactory levels of preparation for engineering studies can not be insisted upon in all cases, we feel that students of genuine promise, but deficient in specific preparation, should be admitted directly to a course in engineering and that this course should be lengthened accordingly. Under such conditions we favor a four-year course for students entering on an optimum level of preparation, and a four and one-half or a five-year course for others. For the sake of greater influence on the offerings of the secondary schools we recommend that these conditions be set forth clearly in college catalogs and guidance booklets.

A besetting danger in engineering education is that our effort to maintain a high standard of work, if misdirected, may lead us to prefer efficient routine to less certain but more educative self-directed effort. There is a real temptation to sacrifice originality, resourcefulness and imagination, on the part of teachers and students alike, to sheer volume of production. As corrective measures, we suggest wider experimentation in the two upper undergraduate years with larger, less frequent and more individual assignments of work, greater freedom of attendance, greater latitude of form and analysis in laboratory problems, fewer exercises and more projects; and the testing of achievement through comprehensive examinations involving not only written and oral work, but an evaluation of reports, designs, drawings, memoirs and other evidences of individual work during term time. The proper direction of this more highly individual work is likely to make heavy demands on time, and ought not to be an added burden for already heavily loaded teachers.

We are firmly committed in principle to the selective handling of students according to ability, not only in the early years, but also in the levels of attainment set for graduation. To the latter end, we commend British example in setting higher requirements and incentives for the degree with honors. The essential features of an honors course, in our opinion, are three-fold, (1) a higher standard of general achievement and particularly in the basic sciences, (2) a larger degree of independent work and (3) a comprehensive final examination as a test of integrated achievement. An autonomous plan of studies is incidental rather than primary to these ends.

We believe that it is not less the duty of the colleges to foster the social qualities of students and their individual initiative, resourcefulness and responsibility, than to foster their intelligence and knowledge. Both academic and non-academic activities may contribute to these ends. We strongly advise against a scholastic program so crowded with detail as to encourage routine methods of work, cut off all opportunity for independent reading and reflection, and practically to exclude the average student from a normal degree of participation in voluntary student activities. We deem it inadvisable to set work requirements which will occupy the average student, working with fair efficiency, more than a normal total of forty-eight hours per week. For students of superior ability we advise an honors course of higher qualitative standards, rather than an abbreviation of normal time requirements.

We reaffirm our belief in the practical advantage of making a distinct break between undergraduate and postgraduate work, rather than establishing a longer curriculum for all schools and all students. The admission of graduate students should be highly selective, as should the choice of a graduate school. In general, we favor specialization by institutions in postgraduate teaching and research and migration by students in quest of special advantages of men, equipment, and environment, recognizing that while comparatively few institutions now afford scientific facilities of the highest order, a considerable number are able to offer a single graduate year of substantial merit.

THE INTEGRATION OF ACADEMIC AND PRACTICAL TRAINING

We attach the highest importance to a closer integration of the work of the schools with the practical training of the engineer, a matter which has had less attention in America than in either Great Britain or Germany. The cooperative plan is our most distinctive contribution to this end. When conducted with proper educational ideals, supported by competent leadership, adequate staff and facilities and a genuine coordination of industrial and scholastic training, it has proved its substantial worth. While the plan seems to merit wider adoption, under proper safeguards, it is not a universal solution of the problem nor probably one suited to a majority of the engineering colleges. The most effective plans of practical training abroad have been set up under the initiative and guidance of the national bodies of the engineering profession with the organized cooperation of the technical industries. Our own professional body has no code of educational qualifications other than the successful performance of engineering work and its policy toward education is one of friendly *laissez-faire*. With a few enlightened exceptions, and these principally in the electrical industry, the practice of American employers is to train men for specific needs, rather than as a phase of a broad professional discipline. Apart from the cooperative plan these conditions tend to place the problem largely beyond the control of the colleges, except where a period of experience is made a prerequisite for graduation. As we see no early prospect of bringing the colleges, engineering societies and industries together for an effective initiative in setting up standards of practical training, we recommend that the Society make a special study of the feasibility of requiring a minimum period of practical training before graduation, a plan now in general force in Germany.

Teaching and Research Personnel

The increasing difficulties met in filling teaching posts o the highest rank point to the need for more positive efforts t develop personnel through postgraduate studies and by co-operation with industries. Some areas are showing fairly serious results from over-intensive industrial recruiting. It appears that a considerably higher standard of scientific attainments is coming to prevail than that anticipated in the preparation of men who entered the teaching field twenty years or more ago and that this fact is beginning to exercise a limiting effect on advancement. A higher scale of compensation in the higher ranks is imperative and is gradually being forced by industrial competition as major vacancies arise.

We are convinced that it will be necessary for educational authorities and the public in general to revise radically their conceptions of the scale of compensation and the degree of freedom and responsibility appropriate for these higher teaching and directive posts. We know of no valid reason why they should be inferior in any of these respects to corresponding posts in industry. It seems clear that college posts must make their appeal primarily through superior opportunities for scholarly attainment and intellectual creation. With the recent growth of research and development work by industries, college posts have relatively lost ground. The opportunities for creative work, the facilities and assistance offered, and the scale of compensation paid have definitely shifted in favor of industrial employment.

Research for new knowledge and the advancement of the art, and the higher forms of consulting service growing out of research must be regarded increasingly as normal forms of activity supplementary to teaching. It is urgent, therefore, that the time, means and incentives for research in engineering colleges should be greatly increased. Of even higher importance than any specific additions to knowledge are the intangible reactions of a vital spirit of inquiry and creation on the normal educational processes. Only so may we hope to overcome the deadening influence of routine and the task system which now weighs so heavily on student and teacher alike.

The research responsibilities of engineering colleges, in our opinion, have not yet been visualized as broadly as they should. While research on technical problems is properly first in magnitude, equal importance attaches to the newer fields—economic, social and human—into which engineering is so rapidly expanding. In particular we believe that engineering colleges ought to assume a special responsibility for researches in the conditions which determine the efficiency of human work. The German technical universities have taken a leading position in this field and are doing much to bring industrial psychology and engineering into effective union. In general, we believe that thorough research in these fields must precede the development of effective teaching materials and methods.

Pubic Support of Technical Education and Research

Intangible as it may seem, probably nothing would do more to advance the interests of higher technical education than a greater appreciation by the public of the work of the technical professions in present day civilization. The work of specific vocational and educational guidance for the adolescent boy should go forward, but a far broader type of ''institutional publicity'' is of the highest importance to our colleges. One has but to observe what the kindling of public imagination has done for medical education and research! The movement in medical education had its beginning in an effort to raise its technical standards from within, but it came to larger fruition only when translated into terms having a wide public appeal. The investigations of the Society have clearly shown the need and have indicated the means for many improvements of detail, but they have also revealed many larger problems which are beyond the powers resident in our colleges as single units. We venture the opinion that the next phase of effort by the Society should be to awaken the public, beginning with the engineering profession and the industries, and reaching out to ever-widening circles of influence, to the importance of engineering education and research as factors in individual and social well-being.

THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

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BULLETIN NUMBER 1
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF ENGINEERING STUDENTS AT THE TIME OF ENTRANCE TO COLLEGE

Conducted under the Auspices of the
Committee on Engineering Students and Graduates

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FOREWORD

This bulletin presents one of a series of fact-finding studies included in a general investigation concerned with ''the objects of engineering education and the fitness of the present-day curriculum,'' which has been carried out during the years 1924 to 1926 inclusive by the Society for the Promotion of Engineering Education under a grant of funds by the Carnegie Corporation of New York.

The investigation has been widely cooperative in method. One hundred and thirty-eight engineering colleges in the United States and Canada participated in an extended series of studies through special committees or correspondents of their faculties. A group of general committees of the Society have prepared reports based on the data supplied by the several faculty committees and compiled by the Staff. The United States Bureau of Education, a group of national engineering societies, and a number of other agencies have contributed important studies. These activities have been conducted under the general direction of the Board of Investigation and Coordination and under the immediate supervision of the Staff, as named elsewhere.

A number of bulletins are based on the studies carried out in cooperation with one or more of the above-named agencies. Other bulletins are based on special studies conducted by the Staff. The work of coordinating and editing the contents of the bulletins has been done by the Staff. Because of the cooperative nature of the project and the many sources drawn upon, individual authorship, in general, is not indicated. The agencies which have cooperated in each study are noted in the introductory section of the corresponding bulletin.

The bulletins are published by the Society through its Board of Investigation and Coordination as the documentation of the investigation, but the responsibility for their contents, for the opinions expressed, and for the recommendations made rests in all cases on the authors and editors of the particular material presented. The more general findings and recommendations of the Board, based upon a synthesis of the several studies, are to be published separately.

ENGINEERING STUDENTS AT TIME OF ENTRANCE TO COLLEGE

Purposes.—The purposes of this study were: *First,* to obtain information which would give as accurate and complete a picture as possible of the antecedents, characteristics, preparatory training and abilities of entering students, and the grounds of their choice of engineering; and *second,* upon the basis of that information, to point out measures which engineering colleges may take to insure the attraction and admission of students who give promise of successful pursuit of an engineering course, and to recommend measures to provide for the early adjustment of those students to college life and engineering study.

Sources of Information.—Data relating to entering students were obtained by means of questionnaire studies carried out through the cooperation of committees of the faculties of thirty-two engineering schools and colleges distributed as to types and locations as follows:

State Universities	9
Privately Endowed Universities	6
Land Grant Colleges	6
Privately Endowed Polytechnic Institutes	3
State Military Colleges	2
Canadian Provincial Universities	2
Privately Endowed Arts Colleges	1
State Schools of Mines	1
Municipal University	1
Territorial University	1

Institutions in New England and Middle Atlantic States	14
Institutions in Middle Western States	9
Institutions in Southern States	4
Institutions in Rocky Mountain States	2
Canadian Institutions	2
Hawaiian Institution	1

The number of students reported upon is 4,079, which is approximately twenty per cent of the class admitted in the fall of 1924. This number of students and the distribution of the institutions are probably such as to insure a fair sampling of the entire group of entering students.

Auspices.—The project was carried out under the sponsorship of the Committee on Engineering Students and Graduates:

R. L. Sackett, *Chairman,* Pennsylvania State College,
E. B. Roberts, *Secretary,* Westinghouse Electric and Manufacturing Company,
Edward Bennett, University of Wisconsin,
J. W. Hallock, University of Pittsburgh,
G. B. Pegram, Columbia University,
R. I. Rees, American Telephone and Telegraph Company,
H. P. Talbot, Massachusetts Institute of Technology.

The committee has presented two reports; one in June, 1925, and one in June, 1926. These two reports with such editorial changes as were needed for the purpose, together with the accompanying tables of data, have been consolidated and constitute the material which follows. It has been divided into two parts. The first is devoted to the evidence collected and to comments thereon; and the second to the committee's conclusions and recommendations. These parts correspond to the two reports of the committee previously mentioned. The opinions expressed are those of the committee.

PART I. DATA RELATING TO ENTERING STUDENTS

(The tables of data referred to will be found on pages 188 to 192 inc.)

Median Age at Entrance.—The median age of entering students in 1924 was 18 years, 10.6 months. This is the median of the median figures reported by the colleges. The minimum median age reported by an institution was 18 years, 2 months; and the maximum 19 years, 6 months.

Birthplace and Parentage.—From Table 2 it is seen that 96 per cent of the students, 74 per cent of their parents, and 61 per cent of their grandparents were born in the United States and Canada. Ninety-one per cent of the grandparents were born either in the United States or Canada or in countries in northwestern Europe. The remaining 9 per cent were natives of southern Europe, Latin-American countries, Slavic countries, and others. Comparatively few students seem to have been derived from the wave of immigration coming in recent years from southern and eastern Europe.

These figures are for the colleges as a whole. Figures for particular institutions, however, show large variations from the average. Several institutions report student bodies with 30 per cent or less of native-born grandparents and 50 per cent or less of native-born parents. These institutions are located in large cities. On the other hand, several institutions report all of their entering students native-born and one Canadian institution reports that 100 per cent of the parents of its engineering students were native-born. In general, it is noted that institutions in southern and western states and in rural sections have a higher percentage of students of native extraction than do those in eastern states and urban sections.

Home Environment.—The data afford a number of interesting sidelights on the cultural and educational environments of the students' homes (See Tables 3 and 4). Approximately 16 per cent of the fathers are professional men, 29 per cent are in positions connected with industry, 22 per cent are in financial and mercantile occupations, 17 per cent are farmers and 15 per cent are in miscellaneous types of employment. A rather surprising number, 42.5 per cent are the owners or

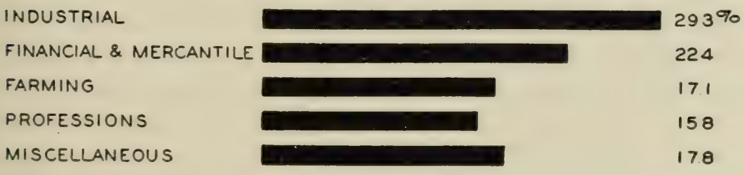

FIG. 1. Business of students' fathers.

proprietors of businesses—including the farmers; 28 per cent are in major or minor executive or supervisory positions; while 19 per cent are either skilled or unskilled workmen. Only 4 per cent are engineers. The remaining 6 per cent are teachers or are in miscellaneous types of positions.

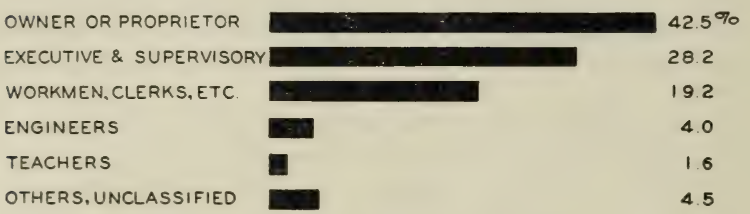

FIG. 2. Positions of students' fathers.

A more detailed analysis of the data, not given by the tables, shows that the professional group is divided: Engineering, 6.3 per cent; education, 2.2 per cent; other professions, 7.3 per cent. It is to be noted that while 6.3 per cent of the fathers are reported as in business of an engineering nature, only 4.0 per cent are definitely engineers. In the financial and mercantile group over twice as many fathers are in small concerns as in large ones. The reverse is true of manufacturing concerns. An analysis of the 42.5 per cent reported as owners or proprietors of businesses shows that 17.1 per cent are farmers and that nearly all of the remainder are proprietors of small businesses, with small mercantile businesses predominating. The positions reported as workmen and clerks are divided: Skilled workmen, 13.0 per cent; unskilled workmen, 2.7 per cent; clerks, 3.5 per cent. The positions reported as engineers are divided: Chief engineer, 1.4 per cent: supervising engineer, 0.8 per cent; assistant engineer, 0.5 per cent; draftsmen, surveyors, etc., 1.3 per cent.

The statistics of the education of the students' parents warrant careful attention. Approximately 13 per cent of the fathers and 5 per cent of the mothers are college graduates. The degrees are divided as follows: Fathers—professional degrees, 6.0 per cent; collegiate degrees, 6.9 per cent; mothers—

professional degrees, 0.5 per cent; collegiate degrees, 4.8 per cent. About 40 per cent of the parents are graduates of high school. Approximately 40 per cent have either a grammar school education or less, about 15 per cent of the fathers and 10 per cent of the mothers have not completed an education extending through grammar school. The contrasts in the education of parents of students in various institutions are striking. One privately endowed eastern university reports that 48.5 per cent of the fathers and 24.3 per cent of the mothers hold college degrees, while another institution reports only two fathers and no mothers who attended college.

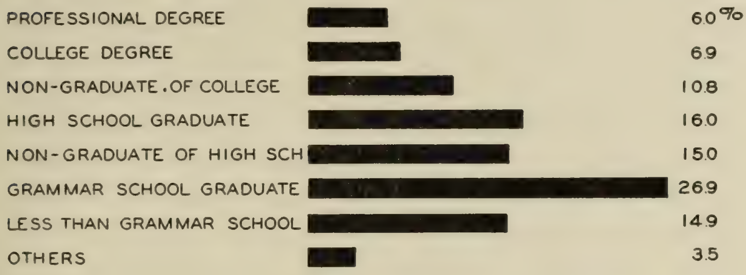

Fig. 3. Education of students' fathers.

It would seem reasonable to conclude that the majority of engineering students come from homes where there is but a limited knowledge of or contact with higher education, and in particular with engineering education. The basis upon which students form decisions to go to college and to study engineering, which will be given later, seems to bear out this conclusion.

Distances and Types of Communities from Which Students Are Drawn.—The distance from which engineering colleges draw their students is small, the median radius (radius of a circle within which half of the students have their homes) being but 107 miles. This is true in spite of the fact that a considerable proportion of institutions located in rural sections are included in the tables. Only three institutions report median radii of 200 miles or more, while eight report 25 miles or less. Only 15 per cent of the students migrate from other states and but 1.2 per cent come from foreign countries. Several of the institutions are quite local in character, having half or more of their students' homes within ten miles of the college.

As might be expected, institutions in rural communities draw students more largely from small towns, villages and farms. One institution, on the other hand, reports that 85 per cent of its students come from cities of over 100,000 population. A considerable proportion of engineering students come from the smaller urban communities, a higher percentage than the distribution of the entire population would indicate. Engineering graduates, on the other hand, migrate to large centers of industry and population. Engineering colleges therefore act as important distributors of young male population from rural to urban centers.

Earnings of Students before Entering College.—It is interesting to note that a very large proportion of students entering engineering colleges worked during the year before they entered and earned and saved substantial sums. Nine students out of every ten reported that they had done a considerable amount of work before entering college. This seems to have been quite universal.

Scholastic Groups Represented.—Since seven-eighths of all engineering students are admitted from public high schools, it is apparent that consideration of preparatory training can be directed principally to those schools.

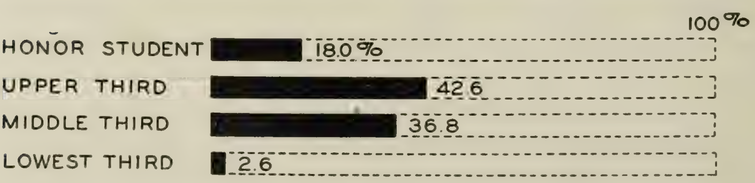

FIG. 4. Students' standing in high school classes. (As given by the students themselves.)

A number of significant indices of the kind and quality of preparatory training are afforded by the answers to a questionnaire submitted to freshmen in the fall of 1924. (See Tables 4, 5 and 6.) From these it appears that engineering colleges are receiving considerably better than an average selection in point of mental ability. From the students' statements it appears that 60 per cent were in the honor group or upper third of high school graduating classes, and that but 2.6 per cent were in the lowest third. *These statements have been confirmed in certain cases by examination of records obtained directly from high schools.* It is to be noted, however, that 11.5 per cent of the students did not give their high school standing. Some of these may have failed to do so because of poor records. The returns from the colleges are remarkably uniform in the percentage of entering students of high standing. No institution reports more than a very small

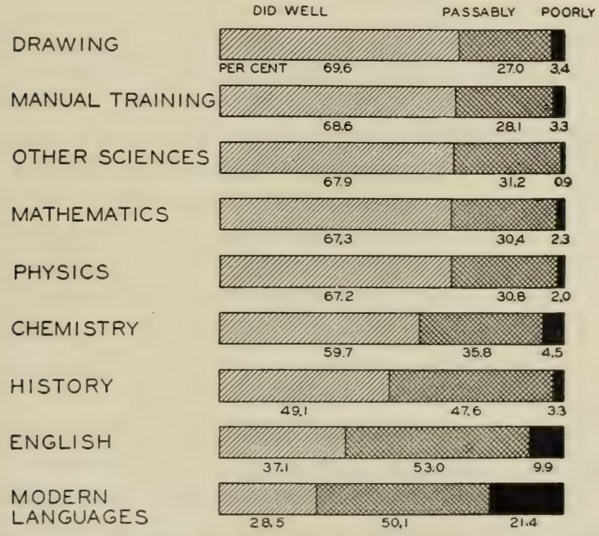

FIG. 5. Students' records in high school subjects. (As given by the students themselves.)

proportion of students drawn from the lowest third of high school classes.

The students' statements indicate that they did well and liked those subjects of the high school curriculum which are fundamental as preparation for engineering courses. Two-thirds did well in mathematics, science, drawing and manual training, and a still larger percentage stated that they had a distinct liking for these subjects. The proportion who did poorly in them is very small, ranging from 1 to 6 per cent.

It appears, therefore, that our students as a whole possess the natural ability needed to succeed in college work (though not necessarily in engineering) and that they did well in high school subjects which form the essential basis of preparation for engineering.

Quality of Secondary School Preparation.—When we turn, however, to the quality of preparation, a different picture is presented. There is ample evidence to show that preparation for engineering courses is seriously lacking in those elements of definiteness and thoroughness which are so essential in the training of the engineer. The fact that one student in every five admitted in the fall of 1924 could not meet the specified entrance requirements, which are not severe, and that one student in eight was conditioned in mathematics at entrance, is an indication of the unsatisfactory kind of preparation which many students receive. Furthermore, even in the case of students who meet the formal requirements, the quality of preparation is far from satisfactory. Many colleges are finding it necessary to place increasing numbers of freshmen each year in special sections in mathematics and other subjects and to devote half or more of a year's work to preparatory courses carrying no college credit. It is evident that the colleges are facing a serious situation in this connection.

Basis of Educational Choices.—If the engineering colleges are to function effectively and if they are to deal with students who have a reasonable chance for success in engineering, it is apparent that consideration should be given to the means of attracting them to the colleges and to the advice and counsel afforded to young men in choosing a career. The facts obtained in this study throw considerable light on these important matters.

In forming a decision to go to college, students appear to have been influenced by advice of parents, teachers or friends to a smaller degree than might have been expected. Approximately one-half of the students indicated that advice had been a factor in their decision to go to college. On the other hand, such reasons as the desire to earn a good living, the desire for a higher education or for general self-improvement were given in a considerably larger percentage of cases. About four-tenths of the students indicated that the desire to become an engineer had been an important factor in their decisions. It is significant that only 10 per cent indicated that the advice of teachers had been a factor in their decision.

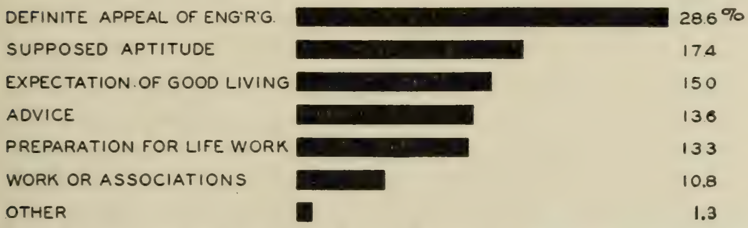

Fig. 6. Relative weight of different factors in students' decision to study engineering.

Advice was a still less important factor in students' decisions to study engineering. Only 24 per cent indicated that they had based this decision upon the counsel of others, and only 5 per cent indicated that they had profited by the advice of teachers. The outstanding reason for the choice of engineering appears to have been its definite appeal; second to that are such reasons as the belief that an engineering training promised to provide a good living.

In the selection of a particular course of study, it is apparent that advice played very little part, since only 10 per cent of the students indicated that advice of parents, teachers or others had influenced them.

It is also important to note that a majority of students entering engineering courses form their decisions to go to college and to study engineering at an early date. More than three-fourths reached a decision to study engineering before graduating from high school, and slightly more than half formed the decision before entering the last year of high school.

As a check on the validity of the basis of the students' decision they were asked to write a short statement of their conception of the field of engineering, of the work of the engineer, and of their understanding of the nature of the particular field of engineering which they had elected to enter. These papers were rated by members of the faculties and gave results indicated in Table 15. It appears that well over half the students have little or no conception or a poor conception of these matters, though they have formed a most important decision on the basis of that conception.

Summary of the Existing Situation.—It appears that students form their decisions to go to college, to study engineering and to pursue a particular course in engineering at an early period, a majority before reaching the last year of high school; that these decisions are largely the result of individual choice, little influenced by advice; and that they are based upon a very imperfect or faulty understanding of the careers to which the students aspire. This situation is evidently one to which serious attention should be given. Is it to be expected that a training so definite and rigorous as that in engineering could be followed successfully by students who enter upon it with so little knowledge of their fitness? While a number of institutions are now endeavoring to supply information to high school principals, teachers and students as to the nature of engineering work and the requirements and characteristics of engineering courses, little more than a start seems to have been made. This is a field of effort which the engineering colleges should develop without delay.

The data gathered in this study have their distinctly encouraging aspects. The concrete evidence as to the origins of our students, their standing in high school and the subjects which they did well and liked, seem to point clearly to the conclusion that our student material is fundamentally good; that the young men on the whole are susceptible of development into highly useful members of society. At the same time, the facts relative to the cultural background from which the students go to college are such as to demand that the general educational elements in engineering curricula should under no circumstances be given less weight or consideration than the elements of scientific and technological training.

In view of the conclusion that our students as a class, considered merely as young men and not primarily as prospective engineers, seem to be of distinctly good quality, serious doubt is raised as to the validity of certain features of an educational program which less than 40 per cent of those entering complete with success. Those who are concerned with elevating the standards of the engineering profession may feel that it is quite proper for us to graduate only that proportion, but what should be said from the viewpoint of the young men themselves?

If our students are of sound extraction and good mentality, four chief reasons may contribute to their elimination: (1) poor preparation in those subjects which form the necessary scholastic foundation for engineering training, and lack of that definiteness and thoroughness needed to prepare for a rigorous college course; (2) lack of effective and valid guidance in selection of an occupation and college course; (3) absorption in the non-essentials of college life; (4) failure on the part of the colleges themselves properly to deal with the student. As the present high proportion of eliminations is due only in part to ineffectual preparation and selection of students, efforts to remedy the situation cannot deal solely with the events leading up to admission but must include as well the early adjustment of the students to college life and work.

PART II. CONCLUSIONS AND SUGGESTIONS OF THE COMMITTEE

Summary of Conclusions.—The conclusions and suggestions of the committee may be condensed into the following summary:

First. There is a definite need for practical aids which will assist the high school student in understanding the nature of an engineering career. Suggested methods include:

(*a*) Conferences of high school and engineering teachers.
(*b*) Addresses to high school students and teachers.
(*c*) Literature especially prepared for high school students and teachers and for parents.
(*d*) Moving pictures, lantern slides, extension methods and radio.

Second. It is important that more discriminating bases of selection and of admission to engineering colleges be developed.

Third. More careful consideration should be given to "orientation" courses and other means of guidance designed to aid students in the early part of their engineering curriculum in obtaining a more definite conception of engineering in general and of the division which they propose to pursue or are pursuing.

The problems of student personnel constitute a field of study much broader than the scope of the present project. Attention is therefore concentrated upon the following specific features which are believed to be of immediate importance:

A. Guidance of high school students in choosing engineering as a career.
B. The problem of admission methods.
C. Orientation and guidance of students after entering college.

A. Guidance of High School Students in Choosing Engineering as a Profession

Present Conditions.—On a previous page it was pointed out that over half of our students decide to study engineering before reaching the last year of high school; that fewer than ten per cent have failed to select a particular course at the time of admission; and further that the advice of parents, teachers, or friends was a factor in reaching decisions in less than one-fourth of all cases. In so far as the advice of parents might depend upon their educational and occupational experience it was noted that about thirteen per cent of the students' fathers and about five per cent of the mothers are college graduates, and that only four per cent of the fathers are engineers. The statements of the students themselves show that the great majority feel they reached the important decision of choice of a career on their own initiative. Apparently they based their choice on the attractiveness of engineering and assumed aptitude for it.

That students arrive at these decisions on the basis of imperfect knowledge and with little or no chance of testing their supposed aptitude, is generally understood. It was therefore to be expected that the results of the test given early in the freshman year, in which they were asked to give their conception of engineering and of their chosen course, would be poor. This proved to be the case, probably in even greater degree than might have been anticipated. As previously noted more than half of the students showed little conception of their chosen field of life work and thus indicated the lack of knowledge on which their decisions were based.

Joint Function of Colleges and Secondary Schools.—In view of the above facts, it seems clear that the engineering colleges should consider ways and means of giving assistance to the prospective student of engineering in choosing his career on a more valid basis. This does not imply that there should be any limitation of freedom of choice, but it does mean that study should be given at least to means of supplying information that will guide and assist the student and his parents and teachers. That this is a proper field of endeavor for the engineering colleges and equally for the secondary schools seems undeniable. It seems pertinent to point out that a much larger proportion of secondary school graduates than is generally realized now go to college and that a considerable proportion of these enter engineering courses. From the best information available it seems certain that not fewer than thirty per cent of all secondary school graduates in this country now enter college. The proportion among the boys is even greater, statistics showing as many as forty per cent. (See *Bulletin, 1924, No. 7* of the U. S. Bureau of Education.) The proportion of male students entering college who study engineering is about fourteen per cent, certainly a significant and important fraction of all secondary school graduates.

Plans for Guidance.—For purposes of guidance it appears that a closer relationship between the engineering colleges and the secondary schools would be mutually beneficial to a high degree; to the colleges, in insuring a better selection of students, and to the secondary schools, in increasing their service to the students in a very material way. To establish this relationship seems to be within the bounds of possibility. As means to that end, the following several methods are suggested:

1. Conferences of high school teachers and teachers of engineering.
2. Addresses on engineering to high school students and teachers.
3. Distribution of specially prepared literature.
4. Other means.

I. Conferences of High School Teachers with Teachers of Engineering—At present there is little or no cooperation on the part of the colleges and secondary schools in dealing with the problem of occupational and educational guidance of students. This is in large measure due to lack of direct contact and conference. Any means which would bring about such contacts should be seized upon. Experience has shown that the interest of high school principals and teachers in this problem leads them to welcome accurate information that provides a clearer picture of what an engineer does and what the college curriculum is. In the larger cities it should not be difficult to make suitable arrangements for such conferences. In other sections, the similar opportunities afforded at conventions of high school teachers, meetings of educational societies, and the like may be utilized.

It should be made plain that the sole purpose of each conference is to assist high school teachers in advising students who are considering engineering as a career so that they may reach their decisions on more valid grounds and not on misconceptions or insufficient knowledge. The fact that mathematics, the physical sciences, and English constitute the essential core of the preparation for engineering should be continually emphasized. A few years ago (in fact, the condition still obtains to a considerable extent) the misconception that preparation for engineering should be based chiefly on manual training was fairly prevalent in certain sections. Thoroughness of preparation in the really essential subjects is often considered of secondary importance. These impressions should be dispelled. In presenting the matter to high school teachers, statements should be made clear, explicit, and devoid of undue or artificial glorification of engineering. It should be made very clear that the engineering colleges are not engaged in any campaign of propaganda to increase enrollments, but that they are vitally interested in enrolling those students who are qualified to profit by an engineering education, and those students only.

While it may be impracticable to reach all high schools by this method, yet if only a fraction are reached directly, there will be an indirect dissemination of knowledge among a large number. It may be feasible for many of the state institutions to invite high school teachers to annual conferences where this topic among others may receive attention and where they may be shown through the laboratories and otherwise gain some visual conception of the conditions under which engineering study is conducted.

Considerable numbers of high school students themselves visit the state institutions from time to time to attend athletic meets, debating and oratorical contests, and for other purposes. In some states these annual gatherings are important affairs, as in Montana, and have yielded excellent results. The presentation of information regarding engineering should dwell upon the fundamental points of preparation and aptitude as well as upon the general content of engineering curricula and the work which the engineer does after graduation.

2. **Addresses to Teachers and Students.**—One of the most

effective means of informing high school teachers and students regarding engineering is by sending well qualified members of the engineering faculties to address high school convocations. Juniors and seniors at least should be included in these meetings and if all four classes were present it might not be necessary to visit each school oftener than once in two or three years. In thirty or forty minutes a general statement can be made covering the four essential points: aptitude, studies to be pursued in high school in preparation for engineering, the college curriculum, and the work of the engineer after graduation. This plan has been adopted by several colleges in recent years and has proved very satisfactory.

In many cases provision has been made for the students to meet the speaker singly or in small groups for personal conference following the address. Where this has been done it is found that the boys ask pertinent and intelligent questions and show a keen desire for the right sort of information and advice. Some of the engineering teachers who have thus met high school boys express surprise and gratification at the number of students requesting interviews and at their keen interest and eagerness for information. *This method appears to offer one of the most effective approaches to the solution of this problem.* Its success depends in large measure upon the qualifications of the faculty members selected for the purpose. They should possess not only the background of knowledge but the right personality and sympathetic understanding of the views and problems of youth.

3. **Literature.**—An almost indispensable means of providing information regarding engineering and of supplementing other methods is the use of descriptive literature. The thought at once suggests itself that an ideal career bulletin of this type would be one of a series covering the entire higher educational field so that the student would be assisted in choosing from among all of the collegiate and professional departments. If this Society can prepare an effective bulletin covering its special field, other groups may follow and in time it may be possible to prepare a comprehensive series of book-

lets regarding the major vocations and the corresponding collegiate courses.

A few principles which might be followed to advantage in the preparation of such literature are:

It should be attractive in form.
It should be in non-technical language.
While covering the essential aspects of engineering, it should be brief.
In order to insure the proper point of view, secondary school teachers should cooperate in its preparation.
Those high school studies which are essential as preparation for engineering and the usual requirements in each should be set forth in a form which is at once explicit and easily understood.
The major curricula should be described in outline.
Each major technical division of engineering should be outlined sufficiently to give the lay reader a good comprehension of it.
The various functional divisions of engineering work (research, design, supervision, administration, sales, etc.) should be discussed in order to make clear the various kinds of work which engineers do.

4. Other Means.—A growing number of institutions are offering instruction by correspondence and by night classes in nearby communities. The extension faculty is therefore in contact with high school superintendents and principals and may thus act as a liaison agency between the engineering division of the institution and secondary schools.

It is probable that the use of radio in supplying information regarding engineering as a vocation has not been taken advantage of as fully as might be. Talks regarding engineering works and the engineering profession would be welcomed by parents and high school boys in many homes, or by teachers and pupils in many schools. If announced in advance those interested would doubtless arrange to hear the talks. These may be concluded with a statement of how additional information and literature could be obtained, so that it would be possible to place the bulletin previously mentioned in the right hands and to supply other information which could then be considered carefully.

A suggestion which seems to have considerable merit is that in each community one or more engineers be selected as advisers, from whom high school students may obtain information and advice regarding engineering as a career. This might be done in cooperation with local organizations of engineers.

It has been suggested that a valuable service which the local chapters of this Society could render would be the institution of annual joint sessions with local high school teachers for the discussion of problems of mutual interest.

Obviously, different methods of approaching the problem of assisting high school students in choosing careers must be adopted in different localities, depending upon local conditions. One or more of the above methods will probably be found suitable and effective under any conditions likely to be encountered.

Summary of Problem.—In conclusion, an excellent summary of this matter presented by the Faculty Committee of the University of Michigan is quoted:

> "... The sub-committee has also received the distinct impression that many boys enter upon the study of engineering, and are encouraged in this by their parents and friends, largely through a belief that an engineering course will lead them directly to a good job upon graduation. It appears likely that the relatively high value placed upon this prospective job at the end of the course may be but the inevitable view of a boy who is already accustomed to a large measure of self-support, and this natural over-emphasis should receive only the kindliest and most sympathetic consideration. The sub-committee has only the warmest commendation for the seriousness of purpose which such a choice connotes, but it believes that the assurance of prompt and remunerative employment is only the first and most obvious fact to be known about a profession before deciding to follow it, and that this should always be followed by others of more permanent and

commanding importance. Of course, there are some who are attracted to engineering by the inherent romance of the profession, by the creative possibilities in it, by the opportunities which it affords for self-expression, and by something of an understanding of what engineering means to the present and future of our civilization. These are exceptional, however, for the evidence is clear and convincing that as a rule high school boys make their choice for or against engineering upon a very imperfect and inadequate understanding of what engineering really is.

"It is right here, as the sub-committee believes, that the present somewhat negative policy of the engineering college of merely declining to admit those applicants who have demonstrated in high school a certain degree of scholastic unfitness might well be supplemented by an aggressive policy of positive selection, with substantial and far-reaching benefits all around. A few individual colleges already recognize the value to themselves of such a policy, and make a practice of distributing to high school seniors, just prior to graduation, pamphlets containing information about the engineering field and pointing the way of entrance into it. The present sub-committee would do more than this, however, having in view a larger service. It believes that ways and means should be found of placing in the hands of high school juniors and seniors and their parents, presumably through principals and teachers, carefully prepared information about engineering and its many and varied relationships with industry and commerce and trade, with the utilization of the known natural resources of the earth and the never-ceasing quest for more, with the building of cities and the great common services of water supply and light and communication and power and sanitation, with the large-scale amelioration of living conditions everywhere through the extended employment of machinery and mechanical appliances, through improved transportation and through the infinitely varied uses of electricity, and especially about the fast increasing burdens assumed by the engineer in devising, building and administering all these things. The emphasis in all these should be placed *not upon the rewards of engineering to the engineer, least of all the recompense in money, but rather upon the difficulties to be overcome, the hardships to be endured, the power to be achieved.* There is enough of high romance in engineering to win the eternal loyalty of many a boy who, under our present policy of letting him grope his own way along, never learns about the really great attractions of the profession. Boys like this ought to have the benefit of just such a far-extending view of the profession of engineering, as of other vocations, before choosing their life work, and the engineering college, which stands in the relation of recruiting agency to the profession, ought to see that they have it. From the standpoint of the profession itself such recruiting as might be accomplished through this means would be of far greater value and significance than any change that is now likely to be brought about by stiffening up the scholastic requirements for entrance. The engineering college has little direct influence upon the scholastic preparation of candidates who apply to it for admission, but it does have the power of attracting the right kind of boys to its portals and it should find opportunities for effectively exercising that power.''

B. Admission Policies

Is a More Selective Plan Needed?—Any inquiry into questions of the quality of student personnel leads to a consideration of admission policies. Detailed discussion of admission requirements and practices is not within the province of this report, and but one broad question as to admission procedure in relation to student personnel is therefore considered; namely, Is there need of any important modification of present methods of admission?

The answer to this question will depend upon fundamental considerations as to the status and function of engineering schools with respect to general education on the one hand and professional education on the other. Engineering education as understood in this country partakes of the nature of both general collegiate instruction and of more strictly professional instruction. The ordinary four-year engineering course is in this connection sufficiently well described as offering two years of general academic education, with strong emphasis on the physical sciences, followed by two years of professional training. The work of the first two years, however, cannot be regarded as an end in itself or as a desirable preparation for various kinds of subsequent professional or non-professional study in various fields, but almost wholly as a necessary preliminary to the engineering studies of the last two years. Almost all students who enter an engineering college hope to go through to graduation and to engage thereafter in the practice of engineering. With such emphasis on the professional element in engineering education the conclusion seems warranted that procedures of admission to engineering schools should embody methods of discrimination not properly applicable to general collegiate courses.

The difficulty in the application of any principle of discriminating selection lies in the fact that no adequately satisfactory means of selecting students at time of graduation from high school has been devised—at least none which seems to satisfy the needs of engineering colleges. Efforts to improve the general status of admission must be directed in large measure to carefully planned work among high school teachers and students to the end that the young men themselves may be enabled to judge of their aptitude and probable liking for engineering and of their chances of success in it.

Evils of Indiscriminate Admission.—Even with the best assistance to high school students the problem will not be wholly solved. Without doubt there will always be a proportion of students applying for admission and thinking themselves qualified, who will prove unfitted to profit best by an engineering education. It would seem that means of identifying these poorly qualified applicants should be constantly sought, and that changes in admission requirements that may be used to save them from entering should be employed. That the desired end can be accomplished with entire satisfaction is extremely doubtful; that it can be done with greater success than at present seems probable; that it is worth a serious effort on the part of colleges so situated as to make such a trial possible seems clear.

It has been shown only too plainly from the results of the investigation that either our present program is not adapted to the needs of a large fraction of those students whom we admit or that the students are not adapted to the requirements of the program, however it may be expressed. For one thing the plain fact that fewer than forty of every one hundred admitted survive to graduate strongly supports this conclusion. In relation to the matter of eliminations, which is closely related to policies of admission, it will be said by some that the engineering colleges are at fault through their failure properly to deal with those whom they admit. In fairness it must be admitted that there is probably some truth in this assertion. The teachers who are in closest contact with the situation will probably themselves be the first to recognize it, though few will lay the entire fault to our methods of instruction and guidance. Nor can all of it be attributed to the inherent difficulty of engineering as an undergraduate program. Some part at least, and apparently a considerable part, must be laid to the indiscriminate admission of the product of secondary schools.

As it is probable that there will be no reasonably satisfactory and widely applicable major change in admission practices in the immediate future, it seems inevitable that a good part of the process of selection and elimination must go on within the colleges themselves. This condition, of course, is true of educational programs generally. The question is how much of this process can be transferred to the stage of entrance. With means now available, with the addition from time to time of other tested means and with intelligent and common sense trial of new methods, it is probable that a significant portion of the selective process can be shifted from within the engineering course, where it is at present, to the initial stage of admission. To this extent, at least, the proper answer to the question as to the need for change in admission methods appears to be in the affirmative. It seems pertinent to add that a stricter adherence to requirements for admission already supposedly in effect may be the logical first step in the desired direction.

C. Orientation and Guidance of Students After Admission

Initial Adjustments.—Measures to assist and guide the student of engineering should not cease with his admission to college.

The hazards of the sudden transition from home life and the close supervision of the high school class room to the freedom of the college campus have been much discussed. For many years the engineering colleges, with their pre-occupation in matters technical, gave little or no attention to this problem, except for the purely voluntary work of a few individuals. Of late years, however, we are beginning to have a better realization of its importance and to appreciate our responsibility for assisting the young man to adjust himself to the methods and life of the college and to choose his course in engineering intelligently.

One of the best of these evidences is the rapidity with which the "Freshman Week" idea has spread from its inception at the University of Maine three years ago. The more general adoption of the plan of placing problems of student guidance in the hands of a single officer, variously known as Dean of Students or Dean of Men, is another evidence. In fact at the present time there is widespread and increasing realization of the necessity of dealing systematically with the many and difficult problems of student personnel. The independent engineering colleges have perhaps been somewhat slower to institute these measures than the colleges of arts. In the universities, it is natural that many of these problems should be dealt with primarily by the institution as a whole, but there are particular phases of personnel problems which can be dealt with effectively only within the engineering department itself.

Two such closely related problems are presented: *First,* that of orientation to the field of engineering as a whole to the end that the student may be imbued with the attitude of the engineer and his work given effective motivation; and *second,* that of providing information and guidance to assist the student in making the best possible selection of a particular engineering course.

Orientation to Engineering.—To secure the most satisfactory solution demands *opportunity for extended personal contact with the student and intelligent, sympathetic study of his personal traits and aptitudes.* In the smaller colleges such opportunities are quite generally afforded; in a few instances in the larger institutions, similar ends are sought through a special personnel officer; but probably in no case are either the methods or results all that the institutions would desire. Whatever other methods are employed none will ever entirely take the place of direct contact of the student with sympathetic and properly qualified members of the faculty. In fact, this means of guiding the student must take precedence over all others. The system or routine through which the contact is afforded must necessarily vary with the local conditions and in any event is of secondary importance.

Choice of a Particular Course.—In choosing a particular engineering course the student's personal preference, if intelligently arrived at, should be the chief factor. The purpose should be to enable him to form such preferences on a valid basis. Some have assumed that efforts to assist the student after entrance in an intelligent selection are futile because ''nearly all have already made a choice.'' That this is not always so is indicated by the fact, for example, that of about five hundred students in one institution, one hundred and forty-four changed their choice of course between entrance and the opening of their second year.

It is the general practice at present not to require the selection of a course until the end of the first year. In fact, curricula of American engineering colleges now have on the average not less than one and one-half years of undifferentiated work. It would seem possible, in this period, to provide reasonably effective means of assisting students to reach intelligent decisions.

The procedures now employed for this end divide into two distinctly different types which are based on quite different principles: (*a*) those applying to entering classes and (*b*) those involving a pre-engineering course of one, two, or more years, as, for example, those now in operation at Columbia University and the University of Pennsylvania. While administrative matters are no doubt an important element in the selection of these plans, type (*a*) is probably to a considerable extent based upon the idea of the desirability of having the student in direct contact with engineering work from the very beginning and thus of making possible not only an early inculcation of the engineering atmosphere and point of view but also an early acquaintance with engineering methods. The purpose of type (*b*) is no doubt to give the student a broader basis of general education as a background before requiring him definitely to select a particular course, or in fact, finally to commit himself to engineering at all.

Engineering in the Freshman Year.—The procedures of type (*a*), aside from the opportunities for advice to be sought by the individual student if he is conscious of a need for help, are most commonly along the lines of so-called ''orientation'' courses. These are held weekly or bi-weekly. In some cases attendance is voluntary, but generally compulsory. While practices differ, it is a common plan for the head of each engineering department to give a talk before these gatherings upon the characteristics, and, doubtless, the peculiar merits of his field of engineering. Other institutions select a single representative to speak of the branches of the engineering profession and another representative to describe the science courses. They subsequently definitely announce consultation hours, when the students may confer with the heads of departments.

A variant of these procedures is to be found in the introduction into the first year of a short course in elementary engineering laboratory, the class, in sections, rotating among several typical laboratories during a semester. Naturally the work in each laboratory is brief and simple but may assist in determining aptitude as well as arousing interest through the introduction of work definitely of an engineering character.

In some institutions arrangements are made for ''personally conducted'' trips of sections of a class through the various laboratories, allowing time for explanation and examination of apparatus or processes, supplemented by trips to various operating plants of different types, or again, attendance at local meetings of engineering societies.

Serving somewhat analogous purposes, are the so-called ''engineering problems courses'' which were instituted at Iowa State College and the University of Washington by Duckering and More. Courses of this type are now being given in quite a few colleges throughout the country. Their purpose is to acquaint the student with elementary fundamental engineering principles and methods and to require him to use his knowledge of mathematics and the sciences in the solution of practical problems. They seem to serve three admirable purposes, arousing the student's interest, giving him something of the flavor of actual engineering computations, and supplying objective evidence of the practical value of studies which he is sometimes prone to believe he will have little use for later.

Pre-Engineering College Course.—The engineering courses which require or embody a pre-engineering college course, type (*b*), endeavor to insure a more carefully considered selection of a career by postponing the time of selection and creating a broader background against which to view the engineering and scientific field, and to enable the student to make his choice in an environment favorable to counsel. There can be no question, in general, of the intrinsic value of such courses in this respect. They are, however, determined in character by other and quite different factors, and in some cases at least, a student pursues his pre-engineering college work in an environment *not conducive to his choice of engineering at all.* The discussion of these aspects would not be possible or advantageous here.

Literature for Reference.—One distinctly valuable suggestion in the matter of aiding the student in his choice of a course which comes from one institution is that of arranging a shelf in the library equipped with selected works dealing with the professions, to which entering students should have access. More commonly, but still rather rarely, a pamphlet containing brief statements regarding each course, the careers of its graduates, and the traits required of those entering each professional field, is prepared and given to all students. This procedure, if the information is kept fresh and if the pamphlets are brief and readable, has some advantage over a series of talks, since the pamphlet may also reach the parents and lead to a better understanding on their part of the fields of engineering activity.

There is undoubtedly merit in all of the above methods. Under the variety of conditions obtaining in colleges throughout the country one or more of them may be found applicable to any particular local condition. While no method yet devised seems wholly satisfactory, many indications of the realization of the existence of the problem and of the increased understanding of it and the many earnest efforts which are being made to solve it are distinctly encouraging.

Value of Partial Curricula.—One other phase of the general consideration of student personnel and one closely related to the admission of students deserves consideration—the problem of what more may be done for students who are admitted but who do not have the chance or ability to achieve the one now recognized definitely successful outcome of an engineering course, namely, a degree upon completion of a four-year program. Even if the present sixty per cent elimination after admission could be reduced by half through wise self-selection of applicants and improved admission tests, more than one-quarter of the students admitted would still not graduate but would be eliminated, in many cases due to unpreventable causes, mainly by the end of the second year. It is a fair question to ask whether or not sufficient attention has been given to the bearing of the program of the earlier years on this by-product of the engineering schools and the possibility of increasing its value. As they come to see that the road to an engineering degree is not for them to traverse, some of these students will pass into other fields of academic study, especially from engineering schools in institutions where other courses are offered. Most of them will, however, go directly into industry or business. Can the earlier part of the curriculum, without injury to the course as a whole, be arranged to afford a more profitable education for these men who cannot complete the entire course? If the end of the second year could mark a more natural and definite possible terminus, it might serve to advantage in letting out a good many students who now go lamely on to a degree.

PART III. TABULAR SUMMARY OF DATA

(Based on 4,079 engineering students, admitted to thirty-two institutions in the fall of 1924, or about twenty per cent of the entire class admitted to all institutions.)

1. Median Age of Students at Time of Entrance—October 1, 1924—18 years, 10.6 months.

2. Birthplace of Students and of their Parents and Grandparents:

Native-born students	96.2%
Native-born parents	73.6
Native-born grandparents	60.7

Native Countries of Grandparents:

United States and Canada	60.7%
Northwestern European Countries	29.4
Southern European Countries	2.6
Latin-American Countries	0.6
Slavic Countries	3.6
Other Countries	3.2

3. Businesses and Positions of Students' Fathers:

Businesses.	
Professions—engineering, education and others	15.8%
Industrial—contracting, manufacturing, and transportation	29.4
Farming	17.1
Financial and mercantile	22.4
Journalism, public service, and miscellaneous	15.4

Positions.	
Owner or proprietor	42.5%
Executive and supervisory of responsible or subordinate rank	28.2
Workmen—skilled and unskilled, and clerks	19.2
Engineers of various ranks	4.0
Teachers	1.6
Others, unclassified	4.5

4. EDUCATION OF STUDENTS' FATHERS AND MOTHERS:

	Fathers.	Mothers.
College or professional degree	12.9%	5.3%
Non-graduates of college	10.8	9.4
High school graduates (including above)	39.7	41.4
Less than full high school course	55.8	55.6
Full grammar school course or less	41.8	38.3
Less than full grammar school course	14.9	10.3
Others, unclassified	3.5	3.3

5. SIZE OF STUDENTS' HOME COMMUNITY:

Rural, including villages up to 500 population	15.0%
Communities of 500 to 5,000 population	24.2
Communities of 5,000 to 25,000 population	22.1
Communities of 25,000 to 100,000 population, or larger	38.7

6. DISTANCES FROM WHICH STUDENTS ARE DRAWN TO COLLEGE:

Median radius in miles	107
(This is the radius of a circle within which 50% of the students have their homes.)	
Minimum median radius in miles	3
Maximum median radius in miles	275
Percentage of students who do or could live at home	24.8
Percentage whose homes are within the state	83.7
Percentage from United States outside of the state	15.1
Percentage from foreign countries	1.2

7. WORK DONE, EARNINGS, AND SAVINGS OF STUDENTS DURING YEAR PRECEDING THEIR ADMISSION TO COLLEGE:

Percentage who worked	90.0
Average per capita earnings	$417.00
Average per capita savings	219.00

KINDS OF WORK DONE:

Farming	13.7%
Selling, office boy work, messenger service, etc.	29.6
Building construction, operating engines or automobiles, repair work, and other varieties more or less closely associated with engineering	49.6
Other varieties	7.1

8. SCHOOLS IN WHICH STUDENTS PREPARED FOR COLLEGE:

Public high schools (85.8% graduates, 1.4% non-graduates)	87.2%
Parochial schools	2.4
Private preparatory schools	6.9
Private tutoring	0.3
One or more years of college (does not include students admitted to advanced standing)	3.0

9. ADMISSIONS TO ADVANCED STANDING:

Ratio of students admitted to advanced standing in engineering courses to total admissions in 1924–25, including transfers from other departments of the same institution, transfers from other engineering colleges, and admissions to advanced standing from other collegiate courses	12.1
Ratio of admissions in advanced standing to freshman admissions	13.7

10. HIGH SCHOOL RECORDS OF ENTERING STUDENTS:

(As given by the students themselves.)

Honor students and those in upper third of class	60.6%
Students in middle third of class	36.9
Students in lowest third of class	2.6

11. RECORDS AND PREFERENCES OF STUDENTS IN HIGH SCHOOL SUBJECTS:

	Did well.	Did passably.	Did poorly.	Liked.	Indifferent toward.	Disliked.
Mathematics	67.3%	30.4%	2.3%	84.1%	12.5%	3.4%
Physics	67.2	30.8	2.0	85.7	12.0	2.3
Chemistry	59.7	35.8	4.5	76.0	17.9	6.1
Other Sciences	67.9	31.2	0.9	77.4	19.4	3.2
Manual Training	68.6	28.1	3.3	77.2	17.7	5.1
Drawing	69.6	27.0	3.4	81.3	14.0	4.7
History	49.1	47.6	3.3	51.3	35.2	13.5
English	37.1	53.0	9.9	33.4	42.5	24.1
Modern Languages	28.5	50.1	21.4	20.8	35.6	33.6

12. Basis of Students' Decision to go to College:

(Students were permitted to indicate more than one reason.)

Advice of parents	32.9%
Advice of teachers	10.1
Advice of friends and others	10.4
Influence of fraternities, college alumni, athletics, etc.	9.0
To be enabled to earn a good living	47.4
To become an engineer	41.6
To obtain a higher education	36.7
For general self-improvement	21.5
Vague desire "to go to college"	7.3
Other reasons	1.3

13. When Decision to Study Engineering was Formed:

Before last year of high school	50.2%
During last year of high school	26.7
After graduation from high school	23.1

14. Basis of Decision to Study Engineering:

(Students were permitted to indicate more than one basis.)

Advice of parents	13.6%
Advice of teachers	4.8
Advice of friends and others	5.8
Work done or associations formed therein	19.2
Definite appeal of engineering work	50.9
Supposed aptitude for engineering	31.0
To be enabled to earn a good living	26.6
Belief that engineering course is good preparation for many lines of work	23.6
Other reasons	2.3

15. Basis of Choice of Particular Course in Engineering:

(Students were permitted to indicate more than one basis.)

Advice of parents, friends or others	10.6%
Work done or associations formed therein	18.0
Definite appeal of the work	65.9
Supposed good opportunities in the field	19.7
Reputation of department of the institution	3.4
Haphazard choice	8.8
No choice made	9.6

16. Time at which Choice of a Particular Engineering Course Must be Made:

	Number of Institutions.
Beginning of Freshman year	12
During Freshman year	1
End of Freshman or beginning of Sophomore year	51
During Sophomore year	9
End of Sophomore or beginning of Junior year	24
End of Junior or beginning of Senior year	3

17. Students' Conception of Engineering as Evidenced Early in Freshman Year:

Little or none	18.7%	
Poor	37.9	56.6%
Good	30.5%	
Excellent	12.9	43.4%

BULLETIN NUMBER 2
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF ADMISSIONS AND ELIMINATIONS OF ENGINEERING STUDENTS

Conducted under the Auspices of the
Committee on Admissions and Eliminations

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ADMISSIONS AND ELIMINATIONS OF ENGINEERING STUDENTS

Purposes.—The purposes of this study were to prepare an accurate and comprehensive statement of the methods of admitting students to schools and colleges of engineering in the United States and Canada; to determine the relative numbers of students graduated and eliminated; to determine the causes of eliminations as accurately as possible; and finally to prepare suggestions for the betterment of admission practices and of the situation as to eliminations.

Sources of Information.—Data relating to admissions and eliminations were obtained in part from reports furnished by committees of the faculties of cooperating institutions and in part from college catalogues. Information from catalogues was compiled for 116 institutions in the United States and six in Canada. Seventy-two faculty committees supplied other information. The number of institutions represented in tables relating to eliminations is given in each of the tables in which such data are compiled.

Auspices.—The project was carried out under the sponsorship of the Committee on Admissions and Eliminations:

H. H. Jordan, *Chairman,* University of Illinois,
G. W. Munro, *Secretary,* Purdue University,
W. D. Emerson, Norwich University,
O. J. Ferguson, University of Nebraska,
T. P. Harrison, North Carolina State College of Agriculture and Engineering,
C. L. White, University of Washington.

The committee has presented two reports during the course of its studies; one in June, 1925, and one in June, 1926. These two reports with such editorial changes as were needed for the purpose, together with the accompanying tables of data, have been consolidated and constitute the material which follows. The opinions expressed are those of the committee.

This material is divided into two parts; the first devoted to the statistics collected and to comments thereon, and the second, to the committee's conclusions and recommendations. These parts correspond, in general, with the two reports of the committee previously mentioned.

PART I. DATA RELATING TO ADMISSION PRACTICES AND TO ELIMINATIONS AND THEIR CAUSES

General Considerations.—Any discussion of the problems relating to the admission of students to the curricula of engineering colleges and schools, and their subsequent elimination therefrom, would be loose and ineffective unless predicated upon careful consideration of the numerous and diverse elements involved in these two processes. Attention should be called at the very outset to the complexity of these elements.

Beyond a mere paper decree as to what the qualifications for admission shall be, the engineering colleges have little direct control over the actual preparation of candidates who apply for admission. The various points of view and standards of instruction prevailing in the public schools of the United States and Canada constitute one of the major elements in the problem. The private and parochial schools introduce a second element of variation and, to some extent, the school systems of foreign countries also have their effect on the situation.

Still more important than these differences which exist in the broad and general sense, are those found to prevail between public schools of the progressive and well-to-do communities and those of the poorer and less progressive places. Frequently these differences in educational efficiency are large even within areas of small geographical extent. Therefore, they affect the admission standards of the local institution vitally and exert a considerable though less direct influence on the distant college to which some of the students may migrate. From this point of view the problems of admission become largely local in character, as do the problems of elimination. Legislatures and state boards of education may, by their acts, accentuate the difficulties encountered in such a situation and frequently they cause embarrassment in maintaining proper college standards.

Economic changes of recent years have greatly increased the educational opportunities of our young men and women. The numbers of students attending our secondary schools have increased correspondingly with attendant ill effects upon the scholastic standards of many schools due to overcrowding and too limited staffs. More of these same poorly prepared graduates of high schools than formerly find it possible to attend college and thus the problem of overcrowding and consequent lack of fundamental preparation has been pushed up into the very gates of our institutions of higher education. Privately endowed colleges and universities have the solution of this difficulty within their own hands, but for state supported institutions the way out is not so clear.

Another element which adds much to the complexity of the problem of admissions is that of the new emphasis laid upon vocational and physical culture subjects in the high schools. The result is that the character of the pre-engineering school training is being greatly modified. It appears that candidates will offer themselves in years to come, who will be less, rather than better, prepared to undertake rigorous college mathematical and scientific work.

Status of Admission Requirements.—The data collected disclose the following facts:

1. Among one hundred and eleven institutions well distributed over the United States and Canada, including the University of Hawaii, and fully representing the various types of institutions which offer engineering courses, the paper requirements for admission are very uniform in the number of high school units required and also, to a large extent, in the kind of units required. Ninety-two per cent of these institutions require a total of fifteen units. Three institutions require sixteen units while six require fourteen or fourteen and

one-half. The nine independent polytechnic institutes reporting show the greatest spread in requirements, their range being from fourteen to sixteen units. Instances of admission requirements below fifteen units occur only among the New England and North Middle Atlantic institutions.

2. All except seven of 116 institutions in the United States admit students on credentials from accredited high schools. Notable exceptions are the Massachusetts Institute of Technology, Harvard, Princeton, and Yale. Nearly eighty per cent hold entrance examinations for those candidates who do not come from accredited high schools. Six institutions have their own entrance examinations in certain subjects. The six Canadian institutions included in the study admit primarily on the basis of entrance examinations set by the Provincial educational authorities.

3. Sixty-five per cent of the institutions specify what one-half or more of the entrance credits shall be. The average specification for mathematics is 2.8 units. Sixty per cent of the institutions require solid geometry. Sixty-one per cent specify one or two units of science. Practically all require three units of English. Forty-eight per cent require foreign languages. Beyond these fixed requirements we may consider the additional credits to be offered as optional over a wide field of selection. Increasingly these options tend to the vocational and physical education subjects. Table 1 on pages 215 and 216 gives a condensed statement of the scholastic requirements for admission to engineering courses.

4. Almost all institutions admit to advanced standing upon the basis of a transcript of the scholastic record in the institution from which the transfer is made. Evidence of honorable dismissal is also required almost universally. Each case is usually examined upon its individual merits, the Dean or a committee on admissions placing the student in the course at a point deemed proper. Many institutions stipulate that such placement is tentative and subject to readjustment if a satisfactory scholastic record is not made. A number of institutions restrict admission by transfer and require superior

scholastic records in the institution from which the transfer is made.

5. Among 8,728 students admitted to fifty-two institutions in the fall of 1924, 1,706 or 19.6 per cent were classed as ''conditioned students.'' The conditions were distributed as follows: mathematics, 67.3 per cent; science, 21.3 per cent; English, 3.8 per cent; languages, 12.4 per cent. Eleven institutions of the fifty-two reporting do not admit conditioned students to their engineering departments. In a majority of these institutions, however, many students not able to satisfy requirements for admission to engineering are admitted to liberal arts courses and later transferred to engineering when entrance conditions have been removed. If such cases were included, the numbers admitted with conditions would be materially increased. The highest percentage of students admitted with conditions reported by any institution is 62.7. Fifteen report percentages higher than thirty. Apparently a considerable percentage of the students admitted with conditions in mathematics have their deficiency in solid geometry and the third half-unit of algebra.

Discussion of Admission Situation.—Attention is drawn to several matters gleaned from these and other data at hand.

a. Except in the matter of elective subjects, the list of entrance credits presented by a graduate of the modern high school is hardly different from that presented by a student twenty-five years ago.

b. Although the catalogue statements of the total number of units required for admission to engineering schools and colleges are fairly uniform and probably adequately high, the quite general admission of ''conditioned students'' nullifies the real and potent influence a fixed standard might exert.

c. In thirteen institutions where figures were available, the percentage of students beginning the sophomore year who had been admitted as conditioned and non-conditioned in mathematics were respectively 38.5 and 60.5. In only one of the institutions did the conditioned men survive as well as the non-conditioned men.

d. The large number of elective subjects in the high school curriculum is confusing to the average boy. Many subjects of his selection do little to develop intellectual power and fitness for college work. They absorb abnormal amounts of the student's time much to the detriment of his fundamental courses. The defence of this system presumably is that the high school's business is to prepare for life's work and not for college work. It is to be noted, however, that as many as 40 per cent of male high school graduates now enter college. (See Table 4, page 219.)

e. A few schools (thirteen out of sixty-five reporting) use the intelligence test as a definite part of their admission system.

f. Several schools (fifteen out of sixty-four reporting) use the personal interview or ''appraisal'' method in selecting their entering students.

g. Physical examinations are given in most institutions to all entering students, but only in a few cases—principally the military colleges and those having cooperative courses—is failure to meet physical and health standards a ground for refusing admission.

h. Eleven institutions of seventy reporting state that they limit their enrollment in engineering courses. Of these eleven, three have never reached their limit of enrollment and hence have not applied the restriction. In six other cases the limitation of enrollment is enforced either as to the entire freshman class or as to the institution as a whole. In these six cases the enrollment in engineering is not equal to the number which could properly be accommodated. In certain other institutions, however, enrollment in engineering is limited to a certain extent by refusal to admit students from the lowest third of high school graduating classes, selection of only the best from among applicants whom the institution is not required by law to admit, and through other requirements or provisions.

Nature of Admissions Problem.—The fundamental problem of admission to engineering courses does not appear to be one of mere shifting of paper requirements but rather one of better grounding in the high school subjects now specified for entrance. Also, the question of guidance in the selection of electives and in the proper course to pursue in individual cases is one demanding more consideration than has been given it by parents and high schools hitherto.

From the above considerations the following questions may be raised: How can the engineering colleges exert a direct and effective influence on the preparatory schools in the way of securing greater emphasis and better instruction in the subjects of the high school curriculum which are fundamental to collegiate study? Also: Is there need of additional selective methods over and above the present system of admitting on scholastic credits alone?

Status of Eliminations.—Among thirty-eight institutions well distributed over the United States and Canada, there is a noticeable uniformity in the percentage of elimination within certain geographical sections, but wide variations appear when the institutions are taken as a single group.

The method of analyzing eliminations by five-year periods is fair and conveys a rather accurate picture of the situation. The following digest of the data at hand is presented:

1. The percentage of students admitted to thirty-eight representative institutions during the five-year period of 1899–1900 to 1903–1904 who graduated in the succeeding period of 1902–1903 to 1906–1907 was 43.5. The percentage of eliminations, therefore, was 56.5. The percentages of eliminations for the succeeding five-year periods are 57.2, 58.1, 62.4 and 61.6 for the two-year period represented by the classes of 1923 and 1924. If the demoted and otherwise delayed students are added to those eliminated, these percentages are increased on an average to about 72 per cent; in other words, 28 per cent of those admitted are graduated in the normal period of four years.

2. The Canadian schools show a lower elimination rate than do the American schools.

3. The New England and Middle Atlantic institutions show a lower rate of elimination than any other geographical group in the United States.

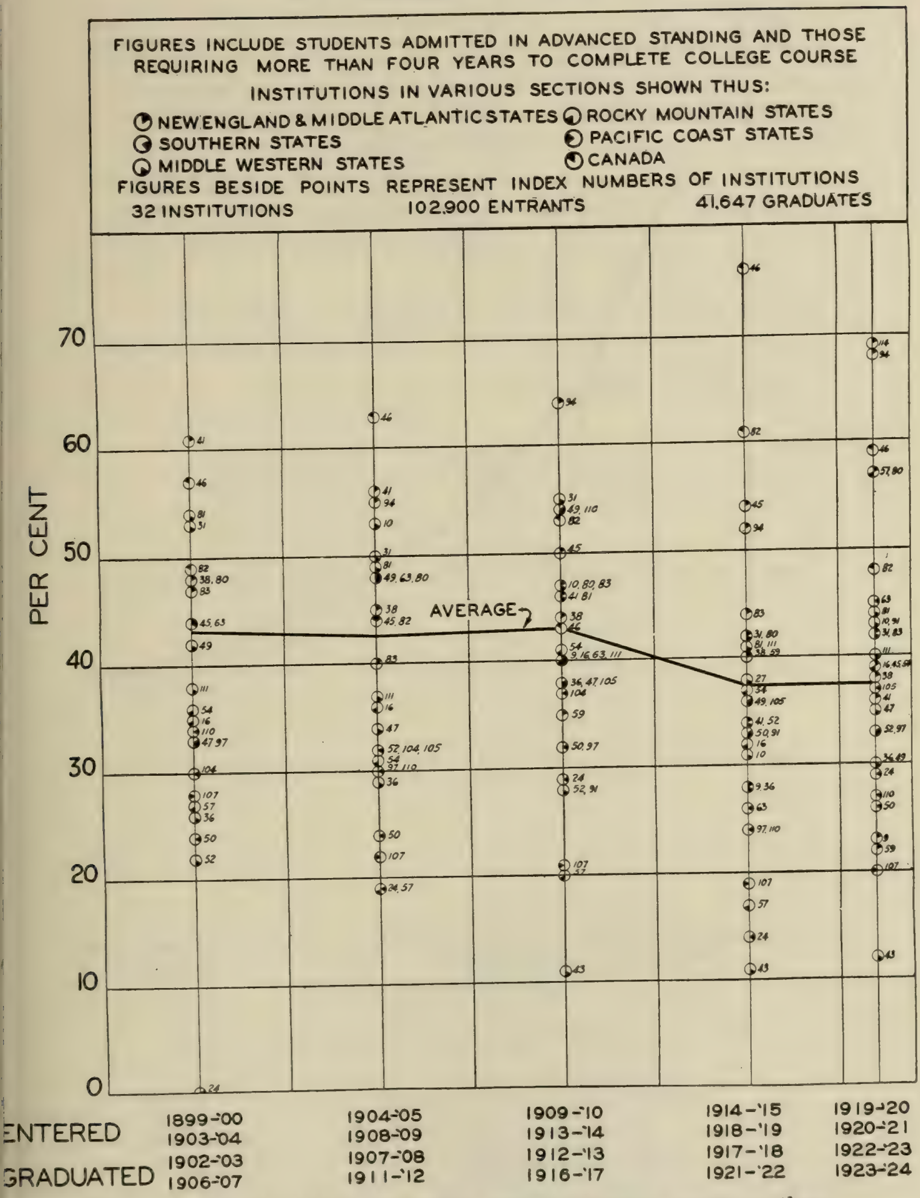

FIG. 1. Ratios of students graduating from engineering courses to those admitted.

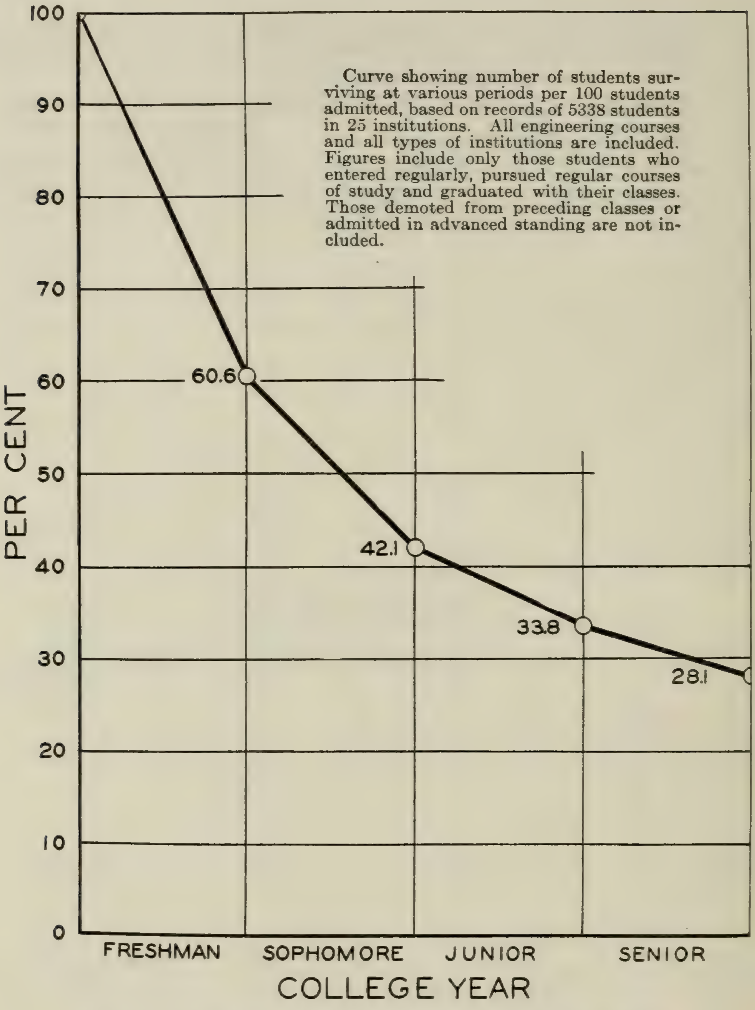

FIG. 2. Curve showing survival of engineering students.

4. The causes of eliminations are various and difficult to determine. The data collected for the classes of 1923 and 1924 in twenty-three institutions show the following figures: Scholastic failure, 53.8 per cent; voluntary change of course, 15.1 per cent; financial reasons, 9.1 per cent; health, 5.5

per cent; dismissal for conduct, 2.7 per cent; family reasons, 1.5 per cent; other reasons, 2.7 per cent; and unknown reasons, 9.6 per cent. These data are subject to question because of the fact that institutions as a whole have not kept accurate records of these matters, but it is significant that the causes of more than fifty per cent of the eliminations in these institutions are ascribed to "scholastic failures."

5. The causes given by the various institutions for the failure of students to do satisfactory work are: Lack of

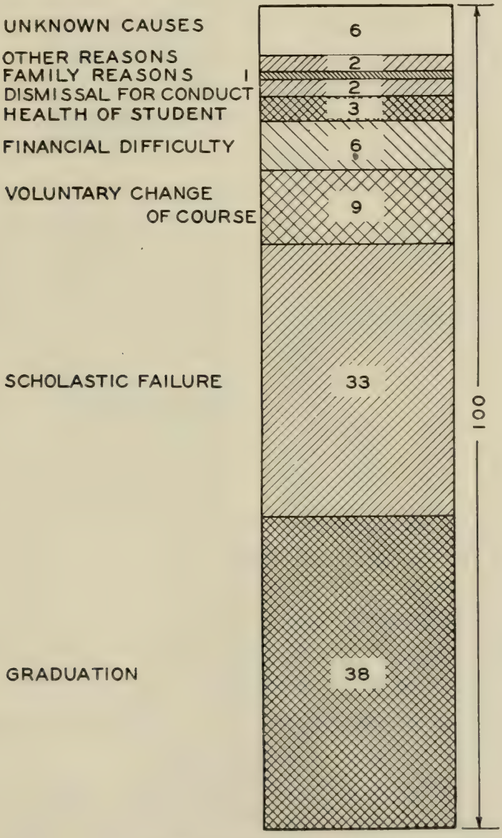

FIG. 3. Graduations and eliminations per 100 entering students and principal causes of eliminations.

ability or of interest, 51.2 per cent; poor preparation, 15.6 per cent; self-support, 8.1 per cent; fraternity life and social activities, 5.7 per cent; health, 4.7 per cent; undergraduate activities, including athletics, 2.8 per cent; failure to remove entrance conditions, 2.7 per cent; other causes, 0.5 per cent; and unknown causes, 8.7 per cent.

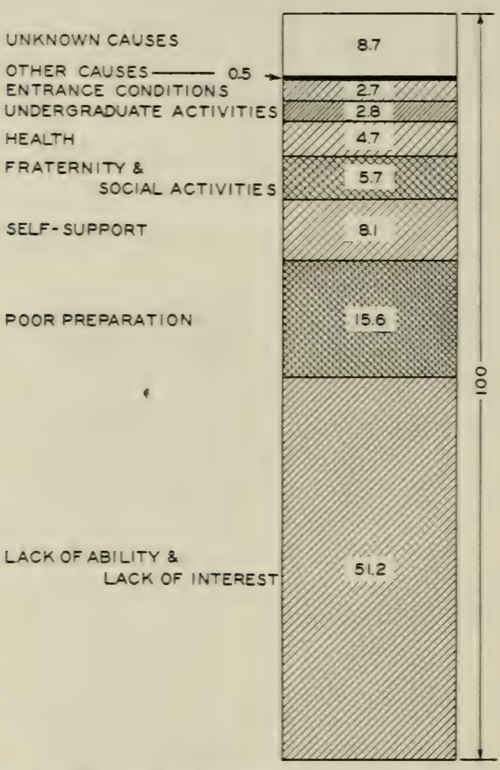

FIG. 4. Causes of scholastic failure per 100 cases.

Discussion of Eliminations.—The following comments are offered upon the matter of eliminations:

a. The elimination rate is high and steadily growing higher. Graduation from engineering colleges in four years is a reality for less than thirty per cent of the students entering these colleges. Graduation at all is a possibility for less than forty per cent of those entering. These figures are tempered somewhat in their severity by the knowledge that a number of students transfer out of engineering colleges and later graduate in other departments of learning. Not all of such students should count in our mortality figures. There are no reliable figures available for liberal arts and science colleges but comparisons with agricultural colleges appear unfavorable to engineering. (See Table 10, page 225.)

b. The rate of eliminations will continue to increase in direct proportion to the failure of the high schools to give training in essential preparatory work, in direct proportion to the increase of distracting influences in both high school and college life outside the class room, and in direct proportion to the lack of balance and stimulus in our engineering curricula. We repeat that it cannot be true, in the main, that students fail and drop out of college because of lack of inherent natural ability. They may not possess engineering aptitude, but the first two years of college work cannot be said to put any great strain upon the bonds of engineering aptitude. It is unfortunate that it was necessary to combine lack of ability and lack of interest into one item in listing the causes of scholastic failures.

c. Over one-half of the total eliminations take place prior to the beginning of the sophomore year.

It must be remembered that the first year in college is a career-finding year and many men discover themselves misplaced in an engineering college leading to an engineering vocation and promptly and properly change, so that the fact of a large elimination the first year does not present an alarming aspect of the situation providing the students dropping out get as much out of their one year of experience as they would anywhere else and providing, further, that the money spent in the process can be justified on this ground. Unhappily the records of these men show poor achievements. The majority are listed as scholastic failures. It is proper to inquire in this connection what may be done to bridge the gap between high school and college so that the jar and shock will be less and the achievement greater.

d. Over twenty-five per cent of the students beginning their junior year do not graduate with their class. This figure corresponds roughly with the elimination rate of colleges of medicine and law.

e. Methods employed by certain institutions to prevent or discourage the unprepared from entering their colleges of engineering have apparently reduced the percentages of elimination and increased the quality of work which they are able to do.

f. In spite of the fact that it is a universally recognized fact that social, athletic and other diversions have increased markedly in the colleges during the last few years, the number of scholastic failures attributed to these causes is small, 8.5 per cent of the total causes.

9. Attention is directed to the apparently more satisfactory conditions prevailing in the Canadian engineering schools. Eliminations appear to be considerably fewer than in the United States. The honors standard in mathematics required for admission in Canada is doubtless a contributing factor.

From the foregoing the following questions may be raised: Is or is it not a correct premise to lay down that nearly every student now entering our engineering colleges is endowed with native ability and enough vocational aptitude to undertake and successfully complete the first two years of college work? Is it not true, also, that our scholastic failures are due in large measure to a lack of preparation in a particular field, namely mathematics? And further, are our engineering students less affected by the diversions and distractions of college life than other students?

Summary of Issues Raised.—The following questions have been raised in the foregoing paragraphs:

1. How can the engineering colleges exert a direct and effective influence on the preparatory schools in the way of

securing greater emphasis and better instruction in the subjects of the high school curriculum which are fundamental to collegiate study?

2. Is there a need for additional selective methods over and above the present system of admitting on scholastic credits alone?

3. What may be done to bridge the gap between high school and college so that the transition will be less of a shock and the achievement of the first year greater?

4. Is it, or is it not a correct premise to lay down that nearly every student now entering our engineering colleges is endowed with native ability and enough vocational aptitude to undertake and successfully complete the first two years of college work?

5. Are our scholastic failures due in large measure to lack of preparation in mathematics, or is this only an index of general unpreparedness for engineering college work?

6. Is the scholastic work of engineering students adversely affected in direct proportion to the known increase in extracurricular activities on a college campus, or does their limited participation in such diversions render them largely immune?

These questions will be considered in Part II which follows.

PART II. CONCLUSIONS AND RECOMMENDATIONS OF THE COMMITTEE

A Routine or a Personal Problem?—As pointed out previously matters relating to the admission and elimination of students are very complex. On paper they seem simple, indeed. Procedures connected with them are often standard in form and rapid in execution. Only in a few instances do the colleges of engineering exercise more than an advisory influence in determining who shall enter their gates. In some institutions both the coming in and the going out are mere matters of ''clerical'' arithmetic. There is nothing inherently personal about either proceeding and perhaps that is well. If simplicity and efficiency are the only tests to be applied, then we may dismiss the whole matter with few words—*cum laude,* as it were.

However, in the view of an average eighteen-year old boy just emerging with his fondest dreams dashed to pieces, after his first disastrous experience with the elimination machine, quite a different picture may be painted. And, also, from the point of view of a profession already crowded at the bottom which has been saved from the onerous burden of another prospective failure, much may be said. Some hold that the educational machinery has been injured by its contact with such a young man and that it is much better for his departure. Others feel that injustice has been done and that no profit is gained from the occurrence. The whole matter cannot be dismissed with a word. It invokes lively interest among all educators since it is known that the ''occurrence'' just mentioned is common to all engineering colleges and takes place in the lives of a disturbingly large number of students. The question arises pointedly and insistently as to what may be done about it.

Premises Accepted.—Nothing of a constructive nature can be said about either the problem of admissions or the problem of eliminations unless predicated upon facts and sound assumptions concerning the purposes and character of the engineering schools, of the students admitted to them, and of the engineering profession itself. In attempting to present something constructive as a result of its studies of the data and opinions, the following broad generalizations have been accepted:

1. Engineering education in this country and Canada is and will continue to be dominantly collegiate in character. Whatever professional aspects it may now have in its later stages cannot be used widely as a basis for imposing more severe admission requirements than can be completed in four years of secondary school preparation. It appears that admissions to engineering colleges will continue, as in the past, to be admissions to fundamentally collegiate curricula with at least the first two years almost strictly of such a character.

2. Students entering engineering colleges now come from the upper scholastic ranks of high school graduates. Sixty

per cent are from the first third of their class. Less than five per cent are from the lowest third. They are said to have done well in those high school subjects which are considered most essential as a preparation for engineering training.

3. The greater proportion of students entering engineering colleges are purposeful and definitely attracted by what they think engineering to be. They mean to graduate from an engineering course. They know the work is hard and choose engineering because it is the life work they wish to engage in and not because it is just the "fashion" to be in an engineering college.

4. Each engineering school draws approximately eighty-five per cent of its students from within the state in which it is located. Its sphere of influence on secondary education is, therefore, localized geographically and limited in character by the political, industrial and economic conditions which prevail in its particular state. The special requirements of any one institution affect secondary education in other parts of the country very little. They serve only to modify the selection of electives for a student who plans to migrate to such an institution.

5. Engineering colleges and schools may be divided into two characteristic groups. On the one hand are those institutions which are privately endowed and on the other are those supported by direct taxation of the people of some commonwealth. The problems of admission and elimination may be solved in essentially different ways by these two groups.

6. The engineering profession is not a closed profession; neither is it served by an auxiliary group of a professional character, as is the case in medicine. There is need for a great number of men within the ranks of the profession who have enough training to do the tasks requiring moderate technical skill. By ability and industry these men may eventually rise to prominence as professional engineers and industrial executives.

7. Engineering graduates do not enter a professional status directly upon leaving college; neither do they attain such a

status by serving a single year of "internship." The tradition of the profession, exemplified and perpetuated by the rules of the national engineering societies, definitely discourages the rapid rise of technical graduates to professional rank.

Conclusions from Facts and Premises.—With these and other fundamental facts in mind, it may be concluded that:

1. Admission to engineering colleges from secondary schools on the basis of graduation therefrom is sound in principle, necessary in the case of tax supported institutions, but attended by much loss of time, money, and human heartache on the part of students coming improperly prepared to pursue an engineering curriculum.

2. Elimination rates are already too high and steadily growing higher. Not over one-third of the students admitted to engineering colleges graduate in four years and not over two-fifths ever graduate. A considerable portion of this elimination is due to natural changes of vocational objective, lack of funds, changes in family affairs, and the like. Nevertheless, a large proportion of our lost students go out with needlessly unsatisfactory scholastic records against them.

3. The primary causes of our high eliminations are:

a. The failure of parents to inculcate proper study habits in the home, through adequate discipline and close supervision of the early mental growth of the present-day boy and girl. It must be remembered that college work is entirely self-directed and self-controlled home study.

b. The over-emphasis, on the part of preparatory school authorities, of various educational theories as to the ultimate purposes of our secondary school system, such as the theory of "training in preparation for life," "stimulating vocational interest," et cetera, and the consequent lack of emphasis upon the more fundamental substance of the high school curriculum. There are many evidences that the high school curriculum is too diversified. A lack in the quality of preparation for college is indicated on many sides.

c. The failure of students entering college to adjust themselves promptly to their new environment. This is due in large part to the intense social, athletic, and other so-called ''college atmospheres'' which prevail in most of our institutions of learning.

d. The stuffing of both high school and college curricula with diverting and informational subject matter which requires little real study and does not develop the intellectual power of the student but which does consume his time.

e. The failure of the colleges to introduce enough flexibility and stimulus into the methods of the first few weeks to encourage a freshman student to rectify an initial failure.

f. The failure on the part of many worthy students to recognize that modern engineering curricula require the most of every student's time and that only the exceptional men may hope to earn a considerable portion of their way and complete an engineering course in four years' time.

g. The absence of that vocational stimulus in the daily work of many students which comes to those who have been able to base their choice of a career upon adequate information about the profession they are entering. The evidence clearly shows that a large number of engineering students enter with no adequate information.

h. One of the almost intangible but none the less certain causes of eliminations is the ''moral failure'' of the student. Initial scholastic delinquency leads quickly to discouragement and dismay at the thought of attaining a goal four years away.

Reactions and Opinions of the Colleges.—In the way of comment on the foregoing there is offered a brief summary of the majority reactions and opinions of the several faculties which have given the data much careful thought and study.

1. Entrance examinations, unless applied quite generally, do little to reduce eliminations in the long run. The elimination machinery is simply transferred temporarily to other and less capable hands. To be highly selective, examinations must be rigid in character. Too rigid examinations are unfair.

2. Additional selective devices, such as psychological tests are not well developed; personal interviews become impersonal and perfunctory with large groups; industrial ex-

perience is likely to lead away from an engineering college training; and probationary periods in college are hazardous unless administered wisely and largely for advisory purposes.

3. It is quite generally agreed that it is not a correct premise to lay down that nearly every student now entering our engineering colleges is endowed with enough native ability and vocational aptitude to complete the first two years of college work with success.

4. An engineering college does not do an injustice to an unprepared student by admitting him on apparently satisfactory credentials and later summarily eliminating him. It may be observed that an injustice is done other students if the unprepared are not eliminated.

Duty of the Colleges.—It appears that only as our engineering colleges become definitely professional in character should more restrictive entrance measures be adopted; that engineering colleges may best serve the profession by remaining on a purely collegiate basis in the earlier stages along with colleges of commerce, agriculture, and liberal arts and sciences and by maintaining the same general admission requirements; that engineering colleges must do more than formerly to orient their freshmen and to impress upon them, without coddling, the absolute necessity of hard work; and that means must be found better to acquaint the prospective engineering student with what engineering really is, its scope, and the preparation essential to college success in this field.

The matter of vocational information just alluded to demands more attention than has hitherto been given it by engineering educators. In spite of the fact that most students have chosen engineering with serious purpose and high motives, the investigations conducted by this Society and by several institutions independently prove conclusively that a large proportion of our student body has been admitted to and eliminated from engineering colleges without gaining any simple and usable concept of what engineering is. A great deal of the work of a modern engineer is done in the cloister of a drafting room or office and cannot be observed and understood as readily as the work of doctors, musicians or other professional men. Furthermore, engineering has become highly differentiated and specialized. Only those can meet the challenge of the profession who are willing to undertake the rigorous training it requires after they have been correctly informed of its opportunities and rewards. Failures in college will be diminished materially when these conditions are fulfilled.

It appears highly desirable that admissions "with conditions" be abolished as rapidly as possible both because of the good effect it will have on the high school curriculum and also on account of the influence it will exert in lessening the "moral failures" in college. It is proved beyond doubt that the casualties among those admitted with conditions in mathematics are much higher than among those not so admitted.

It is important that engineering educators find a means of bringing their influence to bear upon secondary education. It is suggested that this may be done through membership and participation in the affairs of the national and state educational associations. Other groups of educators find it quite convenient to accomplish their ends in this way.

It is suggested that much may be done to steady the student and draw out his best efforts if, in the face of impending voluntary self-elimination, some nearer goal were visible. This goal may be set up in the form of certifications of the work done at the end of each stage and formal admissions to the next stage. Associateships in engineering might properly be issued at the completion of the first two years' work.

Ideals to be Sought.—There can be no doubt on anyone's part as to the chief functions of our engineering colleges. They must serve the engineering profession in very vital ways. In truth, they must put the very sinew and life-blood into it by sending forth from their halls an increasing number of young men who are properly trained and motivated to undertake the arduous path to successful engineering careers. The profession, on the other hand, must furnish an attractive and challenging call to the sturdy and high-spirited among the on-coming youth of the land. The optimum in engineering education and in subsequent professional achievement may be realized only amid those ideal conditions:

1. Where those best qualified for engineering service will seek entrance to the profession through the medium of engineering schools.
2. Where all so seeking will receive fair and impartial trial.
3. Where those not fitted or not vitally interested will be discovered and properly advised without the stigma of failure or the loss of time.
4. Where the ''atmosphere'' of the institution is such that avoidable or ''moral'' failures—the dropping or doing poorly of a task undertaken—would be a disgrace.
5. Where intermediate levels of accomplishment will be recognized and certified.
6. Where the high ideals and the tremendous opportunities of the profession, exemplified and expressed by the engineering teacher, will stimulate each student to high endeavor and challenge his best qualities.

PART III. TABULAR SUMMARY OF DATA

(Based on information compiled from the catalogues of 116 institutions in the United States and six in Canada, and upon data supplied by seventy-two faculty committees.)

1. Analysis of Requirements for Admission to Engineering Courses in the United States.

Type of Institution.	No. of Each Type.	Number of Units in Definitely Specified Subjects.			Number of Units Specified in Mathematics.					Number Requiring.		Number of Units Specified in English.			Foreign Language.		Specified Units in Science.					Entrance Conditions.		
		0–7	7½–9½	10–15	0–2	2½	3	3½	4	Solid Geom.	Plane Trig.	2	3	4	Required.	Not Required.	Total. 0	Total. 1	Total. 2	Physics.	Chemistry.	Permitted.	Not Permitted.	No Statement.
State Universities	38	16	9	13	7	4	23	1	3	24	4	1	36	1	15	23	15	18	5	10	1	23	8	7
Land Grant Colleges	20	8	11	1	3	4	10			9			20		3	17	10	10		3		10	6	4
Other State Institutions	6	2	3	1		7	4	1		6			6		2	4	3	2	1	3	1	4	1	1
Privately Endowed Arts Colleges	7	1	5	1	3	4	1	1		2		1	6		6	1	3	3	1	1	1	3	1	3
Privately Endowed Universities	26	5	8	13	4	1	10	5	3	15	7		25	1	17	9	9	13	4	7	3	12	3	11
Privately Endowed Poly. Institutes	9		3	6	1	2	3	2	3	8	4		9		8	1		5	4	5	5	5	1	3
Municipal Institutions	2	1		1		1	1			2			2		1	1	1	1				1		1
Military Colleges	3	1	2		1	2				1		1	2		1	2	2	1					1	2
Totals	111	32	41	31	19	25	52	10	9	67	15	3	106	2	53	58	43	53	15	29	11	58	21	32

Total number of units required for admission:
14 units required by 1 institution
14½ units required by 5 institutions
15 units required by 102 institutions
16 units required by 3 institutions

1. (*Continued.*) ANALYSIS OF REQUIREMENTS FOR ADMISSION TO ENGINEERING COURSES IN THE UNITED STATES.

Location of Institution.	No. of Each Type.	Number of Units in Definitely Specified Subjects.			Number of Units Specified in Mathematics.					Number Requiring.		Number of Units Specified in English.			Foreign Language.		Specified Units in Science.					Entrance Conditions.	
																	Total.						
		0–7	7½–9½	10–15	0–2	2½	3	3½	4	Solid Geom.	Plane Trig.	2	3	4	Required.	Not Required.	0	1	2	Physics.	Chemistry.	Permitted.	Not Permitted.
New Eng. and Mid. Atlantic States. .	36	1	11	24	4	4	12	9	7	27	12		37		30	7	9	21	6	9	6	16	4
Southern States.	22	10	10	2	3	9	8	1	1	6	1	1	19	1	3	18	15	6	1	2		9	7
Middle Western States.	32	16	11	5	4	7	21			23			33		11	22	12	17	3	11	2	21	5
Rocky Mountain States.	13	4	4	5	5		8			8			12		5	7	4	5	4	6	1	9	3
Pacific Coast States.	8	3	5		3	1	3		1	3	2	2	5	1	4	4	3	4	1	1	2	3	2

2. ANALYSIS OF ENTRANCE CONDITIONS.

Institution Number.	Total Freshmen 1924–25.	Total Conditioned Freshmen 1924–25.	Total Students Conditioned in Each Subject.					Units of Math. Required.	Percentage of Freshmen Conditioned.	Percentage of Conditions in Math.
			(*a*) Math.	(*b*) Science.	(*c*) English.	(*d*) Languages.	Others Where Given.			
1	72	43	13	8	9	13		3	59.7	30.3
2	296	0						3	0.0	
3	88	0						2	0.0	
5	121	0						2½	0.0	
6	85	49	45	12	2	20		3½	57.6	91.8
9	354	106	61	18	5	31		3	30.0	57.5
14	107	4	1		1			2	3.7	25.0
16	212	91	59	18	2	24		3	42.9	64.8
24	90	0						4	0.0	
27	63	0						3	0.0	
28	28	1			1			3½	3.6	0.0
30	85	22	18	4				3	25.9	81.8
31	499	0						3	0.0	
34	110	21	6		1	17		2½	19.1	28.6
35	374	227	212	50				3	60.7	93.4
36	186	2						3	1.7	0.0
38	121	8		1		6	1	3½	6.6	0.0
41	146	84	59	1		24		3½	57.5	70.2
43	140	36	24	3		9		3	25.7	66.7
44	82	0						3	0.0	
46	125	36	15	4	9	8			38.8	41.7
47	149	15	4	6				3	10.6	26.6
49	453	162	120	87				3	35.8	74.1
51	18	0						2½	0.0	
52	102	8	2		3		3	3	7.8	25.0
54	148	71	54	27				3	48.0	76.1
—	50	2	2						4.0	100.0
56	218	75	29	23	13	7		2½	34.4	38.7
57	83	27	26	9	2			3	32.5	96.4
58	28	2	2						7.1	100.0

2. (*Continued.*) ANALYSIS OF ENTRANCE CONDITIONS.

Institution Number.	Total Freshmen 1924–25.	Total Conditioned Freshmen 1924–25.	Total Students Conditioned in Each Subject.					Units of Math. Required.	Percentage of Freshmen Conditioned	Percentage of Conditions in Math.
			(*a*) Math.	(*b*) Science.	(*c*) English.	(*d*) Languages.	Others Where Given.			
59	125	46	8	22		1	15	3	36.8	17.4
63	285	8	8					2½	2.8	100.0
64	155	47	41			7		3	30.3	87.3
70	65	15	10	5				3	23.1	66.7
74	220	30	26					2½	13.6	86.7
80	37	0						4	0.0	
81	645	75	74				1	3	11.6	98.7
83	388	83	83		2	6		3	21.4	100.0
86	254	11	5		1	1	4	4	4.3	45.4
87	32	5	2			3		3	15.6	40.0
88	19	5				5			26.3	0.0
91	83	52	35	39				3	62.7	67.3
92	49	7						2	14.3	0.0
97	516	55						3	10.7	0.0
100	66	2	2					2½	3.0	100.0
101	119	0						3½	0.0	
104	167	12					12	2	7.2	0.0
105	306	0						3	0.0	
106	239	95	75	20					39.7	79.0
109	20	0						2½	0.0	
112	145	42	21	3	7	20		3½	29.0	50.0
114	160	24	7	4	6	10		3	15.0	29.2
Totals	8,728	1,706	1,149	364	64	212	36		19.6	67.3

Percentage of freshmen entering with conditions	19.6
Weighted average, units of required mathematics	2.8
Percentage of freshmen entering with conditions in mathematics	13.2

Distribution of Conditions	% of Conditioned Freshmen
Mathematics	67.3
Science	21.3
English	3.8
Languages	12.4
Others	2.1
Total	106.9*

* Some freshmen enter with conditions in more than one subject.

3. EFFECT OF ENTRANCE CONDITIONS IN MATHEMATICS.

Institution No.	Total Freshmen admitted 1923 or 1924.	Percentage of Freshman Class Conditioned in Math.	Students not Conditioned in Mathematics.		Students Conditioned in Mathematics.		Percentage Surviving to Begin Sophomore Year.	
			Began Freshman Year.	Began Sophomore Year.	Began Freshman Year.	Began Sophomore Year.	Not Conditioned in Math.	Conditioned in Math.
16	367	29.2	260	130	107	29	50.0	27.1
30	60	40.0	36	28	24	19	77.8	79.2
35	303	53.8	140	58	163	43	41.4	26.4
41	160	36.2	102	78	58	41	76.4	70.7
43	133	33.1	89	63	44	27	70.8	61.3
46	89	9.0	81	50	8	2	61.7	25.0
49	406	21.7	318	139	88	35	43.7	39.8
54	148	35.2	94	72	54	13	76.5	24.1
70	79	27.8	57	48	22	12	84.2	54.1
74	235	12.4	206	144	29	17	70.0	58.6
90	63	54.0	29	19	34	19	65.5	56.0
106	239	31.4	164	113	75	23	69.0	37.0
112	149	16.1	125	88	24	8	70.4	33.3
Totals	2,431	31.4	1,701	1,030	730	288	60.5	38.5

4. PREPARATION OF FRESHMEN ADMITTED IN FALL OF 1924.

Public high schools	87.3%
Parochial high schools	2.4
Private preparatory schools	7.0
Private tutoring	0.3
One or more years of college, not including admissions to advanced standing	3.0
Ratio of admission in advanced standing to total admissions	12.1

5. STATISTICS RELATING TO GRADUATES FROM PUBLIC HIGH SCHOOLS AND NUMBER OF GRADUATES CONTINUING THEIR EDUCATION IN 1921–22.

(Compiled from Bulletin, 1924, No. 7, ''Statistics of Public High Schools 1921–22'' of the U. S. Bureau of Education.)

	Total Number of Students.	Number of Male Students.
Total number of graduates, 10,977 schools reporting	243,648	99,331
Number going to college	76,588	39,558
Going to other institutions	34,972	10,063
Total students continuing their education	111,560	49,621

Percentage of male students going to college	39.8%
Percentage of male students continuing their education	50.0%

(Compiled from Bulletin, 1924, No. 20, ''Statistics of Universities, Colleges, and Professional Schools 1921–22'' of the U. S. Bureau of Education.)

Total number of students in universities, colleges and professional schools	618,555
Total number of male students in these institutions	402,036
Total number of engineering students	56,649
Ratio of engineering students to total male students	14.1%

6. Admissions to and Graduations from Engineering Courses.

Table shows total number of students entering in a given period and total number graduating in a corresponding period four years later.

38 Institutions Included.

Total number admitted in 1899–00 to 1903–04 inclusive	14,394
Total number graduated in 1902–03 to 1906–07 inclusive	6,257
Ratio of graduations to admissions in per cent	43.5
Total number admitted in 1904–05 to 1908–09 inclusive	22,914
Total number graduated in 1907–08 to 1911–12 inclusive	9,807
Ratio of graduations to admissions in per cent	42.8
Total number admitted in 1909–10 to 1913–14 inclusive	26,300
Total number graduated in 1912–13 to 1916–17 inclusive	11,447
Ratio of graduations to admissions in per cent	43.5
Total number admitted in 1914–15 to 1918–19 inclusive	31,996
Total number graduated in 1917–18 to 1921–22 inclusive	12,056
Ratio of graduations to admissions in per cent	37.6
Total number admitted in 1919–20 to 1920–21 inclusive	21,098
Total number graduated in 1922–23 to 1923–24 inclusive	8,102
Ratio of graduations to admissions in per cent	38.4
Grand total, number admitted 1899–00 to 1920–21 inclusive	116,702
Grand total, number graduated 1902–03 to 1923–24 inclusive	47,669
Ratio of graduations to admissions in per cent	40.8

7. Student Survival.

Survival of Students who Entered Regularly, Pursued Regular Courses of Study and Graduated with their Class.
(Students demoted from preceding classes, or admitted in advanced standing are not included.)

Institution Number.	Class.	Began Fresh. Year.	Percentage.	Began Soph. Year.	Percentage.	Began Junior Year.	Percentage.	Began Senior Year.	Percentage.	Graduated.	Percentage.
3	1924	67	100	29	43.3	18	26.9	18	26.9	14	20.9
5	1923	51	100	31	60.8	17	33.3	10	19.6	9	17.6
9	1924	350	100	221	63.1	131	37.4	106	30.3	87	24.9
16	1923	207	100	121	58.4	86	41.5	71	34.3	65	31.4
24	1923	83	100	31	37.3	22	26.5	18	21.7	16	19.3
31	1923	711	100	331	46.6	221	31.1	142	20.0	117	16.5
36	1923	277	100	229	82.6	173	62.4	117	42.2	94	33.9
38	1924	103	100	58	56.3	48	46.6	43	41.7	42	40.8
41	1924	201	100	115	57.2	83	41.3	70	34.8	60	29.9
46	1924	160	100	89	55.6	72	45.0	62	38.8	48	30.0
47	1924	214	100	139	65.0	87	40.7	82	38.3	71	33.2
49	1924	284	100	143	50.3	103	36.3	82	28.9	62	21.8
52	1924	79	100	74	93.7	27	34.2	22	27.8	18	22.8
54	1923	103	100	54	52.5	33	32.1	30	29.1	28	27.2
59	1924	122	100	66	54.1	38	31.1	34	27.9	34	27.9
62	1923	92	100	60	65.2	53	57.6	48	52.1	36	39.1
63	1924	141	100	79	56.0	62	44.0	55	39.0	53	37.6
64	1923	70	100	31	44.3	16	22.8	13	18.6	10	14.3
80	1923	21	100	17	81.0	12	57.1	9	42.8	7	33.3
81	1923	751	100	514	68.4	358	47.7	289	39.4	269	35.8
83	1923	351	100	225	64.1	170	48.4	137	39.1	106	30.2
86	1924	83	100	48	57.8	34	41.0	21	25.3	21	25.3
91	1924	59	100	35	59.3	28	47.5	24	40.7	20	33.9
93	1923	141	100	93	66.0	69	48.9	63	44.7	54	38.3
98	1924	191	100	152	79.6	123	64.4	115	60.2	115	60.2
100	1924	65	100	39	60.0	31	47.7	21	32.3	17	26.1
105	1923	170	100	111	65.3	87	51.2	70	41.2	65	38.2
110	1923	142	100	61	43.0	25	17.6	20	14.1	15	10.6
111	1923	435	100	276	63.4	181	41.6	142	32.6	109	25.1
Totals		5,724	100	3,472	60.6	2,408	42.1	1,934	33.8	1,661	28.1

8. CAUSES OF ELIMINATIONS OF ENGINEERING STUDENTS

Institution Number.	Scholastic Failure.	Health of Student.	Voluntary Change of Course.	Financial Difficulty.	Dismissal for Conduct.	Family Reasons.	Other Reasons.	Unknown Causes.	Total Cases.
5	14	1	2	2	2	3	1	4	29
10	151	21	24	36	13	4		6	255
10	226	19	25	31	11	1			313
10	139	16	16	26	5	1			203
10	128	11	20	25	6	1			191
24	24	5	13	9	4		3	9	67
38	8	2	32	4	2			20	68
41	46	15	41	7		4		17	130
43	12	7	10	7	11	2	3	20	72
46	81	1	1	1		1		27	112
47	20	2	16	3	2	1	4	19	67
52	13	1	3	21	1		1	11	51
54	35	1	25	9			1	4	75
80	7		2	1	4				14
83	177	10	31	6	1	4	5	11	245
86	37	1	18	1	1			4	62
91	8	1	8	5			11		33
94	20	6	11	2	3	9		5	56
98	36	6		3			10	21	76
100	30		11				2	5	48
103	13	1	14	1	1		3	6	39
104	99	5	14	2	6	4	6	20	156
105	60	4	5		5		6	25	105
110	35	3	26	13				26	103
111	61	12	42	28		3	11	6	163
111	51	4	25	18		4	11	7	120
114	17	2	1	1	1		1	3	26
Totals	1,548	157	436	262	79	42	79	276	2,879
Per cent of total cases	53.8	5.5	15.1	9.1	2.7	1.5	2.7	9.6	100.0

9. CAUSES OF SCHOLASTIC FAILURE OF ENGINEERING STUDENTS.

(Data Obtained from College Records.)

Institution Number.	Entrance Conditions.	Poor Preparation.	Lack of Ability or Lack of Interest.	Undergraduate Activities Including Athletics.	Fraternity and Social Activities.	Self-Support.	Health.	Other Causes.	Unknown Causes.	Total Cases.
9		23	89	9	6	7	2		3	139
16	1	2	4	1	4	7	1		3	23
24	6	10	7	1	7	1			8	40
31		15	29	4	5	3	13	3	9	81
41		27	74	3		2	4		27	137
47		1	16	2					1	20
52		5	8							13
54	4	10	13	1	1	1	3		2	35
57		1		1	1		1			4
62	15	5	5			4				29
74			4	1		2	1			8
91		13	6	1	1	1	1			23
100		2	5		4				1	12
111		36	233	3	26	50	19	2	30	399
Totals............	26	150	493	27	55	78	45	5	84	963
Per cent of total cases...........	2.7	15.6	51.2	2.8	5.7	8.1	4.7	0.5	8.7	100.0

10. STATISTICS ON ADMISSIONS TO AND GRADUATIONS FROM VARIOUS PROFESSIONAL AND COLLEGIATE COURSES.

Name of Course.	No. of Institutions Reporting.	Period Covered by Reports.	Length of Course in Years.	Admission Requirements.	Total Number Admitted.	Total Number Graduated.	Ratio of Graduations to Admissions in Per cent.
Medicine	7	1915 to 1924	4	Min. 2 years college work	3,252	2,493	76.6
Dentistry	3	1917 to 1924	4	Min. 1 year college work	1,393	840	60.3
Law	4	1915 to 1924	3	Min. 2 years college work	2,790	1,644	59.0
Business administration	1	1916 to 1924	4	Graduation from high school	3,385	2,097	61.7
Business administration	1	1919 to 1924	2	Graduation from college	1,218	604	50.0
Agriculture	5	1915 to 1924	4	Graduation from high school	4,777	2,626	54.6
Engineering	38	1914 to 1924	4	Graduation from high school	53,094	20,158	37.8

BULLETIN NUMBER 3
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF ENGINEERING GRADUATES AND NON-GRADUATE FORMER STUDENTS

Conducted under the Auspices of the
Committee on Engineering Students and Graduates

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ENGINEERING GRADUATES AND NON-GRADUATE FORMER STUDENTS

Purposes.—The purposes of this study were to obtain as accurate and complete information as possible regarding the careers of engineering graduates and the relationship of their work to courses pursued in college; to determine the means through which they obtain first positions; to gather information regarding their early experiences and adjustments to industrial life; and to obtain their opinions regarding various phases of engineering education. It was also the purpose to prepare recommendations on various matters relating to engineering graduates, particularly in relation to the placement process and to the continuation of study after leaving college.

Sources of Information.—Data relating to engineering graduates and former students were obtained by means of questionnaire studies carried out through the cooperation of committees of the faculties of a representative group of engineering colleges in the United States and Canada. The following numbers of institutions and of graduates are represented in the tabulations:

1. Recent Graduates—Classes of 1922, 1923, and 1924—43 institutions and 3,933 graduates, representing 47.9 per cent of those canvassed.
2. Older Graduates—Classes of 1919, 1914, 1909, 1904, 1899, 1894, 1889, and 1884—34 institutions and 2,336 individuals, representing 35.2 per cent of those canvassed.
3. Former Students, Non-Graduates, of the classes of 1924, 1919, 1914, 1909 and 1904—14 institutions and 721 individuals, representing 21.5 per cent of those canvassed.

Approximately one-sixth of all engineering graduates of the classes of 1922, 1923 and 1924 are included in the tables. This is probably a fair sampling of the more recent graduates. The number of older graduates is a much smaller percentage of the whole body of graduates of classes prior to 1922. It is felt, however, that the method of sampling by canvassing classes of each fifth year and of institutions representing the various types and geographical locations of engineering colleges gives a fair cross-section of the older graduates. It is believed, therefore, that the information is sufficiently representative to warrant definite conclusions. It is doubtful, however, if the returns from non-graduates are sufficiently complete to warrant other than the most general inferences.

Auspices.—The study was carried out under the sponsorship of the Committee on Engineering Students and Graduates:

R. L. Sackett, *Chairman,* Pennsylvania State College,
E. B. Roberts, *Secretary,* Westinghouse Electric and Manufacturing Company,
Edward Bennett, University of Wisconsin,
J. W. Hallock, University of Pittsburgh,
G. B. Pegram, Columbia University,
R. I. Rees, American Telephone and Telegraph Company,
H. P. Talbot, Massachusetts Institute of Technology.

The committee has presented two reports; one in June, 1925, and one in June, 1926. These two reports with such editorial changes as were needed for the purpose, together with accompanying tables of data, have been consolidated and constitute the material which follows. It has been divided into two parts corresponding to the two reports mentioned. The first presents the information and statements of opinion gathered from graduates. The second sets forth the conclusions and recommendations of the committee.

PART I. DATA AND OPINIONS OBTAINED FROM ENGINEERING GRADUATES AND NON-GRADUATES

(The tables of data referred to will be found on pages 256 to 271 inc.)

A. OCCUPATIONS AND EARNINGS OF GRADUATES

General Fields of Activity.—In Tables 1 to 5 inclusive are exhibited statistics relating to the important and much discussed question of the actual occupations of engineering graduates and the relation of lines of occupation to courses of study.

Table 1 presents the general classification of fields of work of graduates who have passed through the somewhat unsettled first five-year period; 25 per cent state that they are in work of a definitely professional character, 41 per cent in the general industrial field, 16 per cent are in commercial positions, 4.5 per cent are doing financial work, and the remaining 13 per cent are either in governmental employ or are in miscellaneous types of positions. A comparison of the fields of work of graduates of earlier and later classes indicates that a greater proportion of the former class themselves in the professional group, and a smaller proportion in the industrial and financial groups. On general consideration it seems unlikely that any considerable proportion of the graduates of a given class turn with increasing experience from industrial and financial positions to those of a more strictly professional character. Hence it seems probable that this larger showing of the older classes in the professional groups means that in former years the engineering graduate was more intent upon private professional work, and that of late years graduates are going to an increasing extent into the employ of industrial concerns. It is possible, of course, that the replies—particularly those from the older classes—are not strictly representative, but other information not shown in the tables tends to confirm the conclusion that the independent private practice of engineering is distinctly on the decrease and that engineers to a greater and greater extent are going into the employ of corporate organizations, particularly of the large industries.

Occupations as Related to Course Pursued in College.—Tables 2 and 3 and Fig. 1 show the relationship of fields of work of graduates to courses pursued in college. Fig. 1 is a composite of the data of Tables 2 and 3. In both tables and figure the ''same field'' includes those sub-divisions which are usually recognized as a part of the major field itself. Sanitary and hydraulic engineering, for example, are taken as parts of civil engineering. ''Closely associated fields'' are those closely related to the major fields, such, for example, as marine engineering as related to mechanical engineering. ''Unassociated engineering field'' may be illustrated by the case of a graduate of civil engineering who is employed in electrical engineering work. It will be noted that 60 per cent of all graduates who supplied information are in the same lines of work as their college courses, approximately one-quarter are in ''closely associated'' or ''unassociated'' lines of engineering, and the remaining 15 per cent have left engineering.

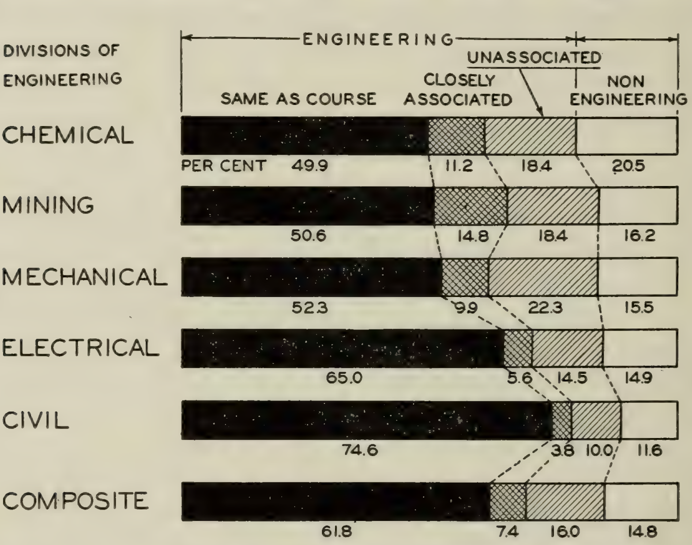

FIG. 1. Relationship of fields of work of engineering graduates to college courses.

These figures seem to disprove the statement so often heard that large proportions of graduates leave engineering for other activities. A comparison of the tabulations of recent and older graduates shows that there is some drift away from fields directly related to college courses, but not more than would seem to be entirely healthy. More civil engineering graduates remain in lines of work directly related to their college course than other groups of graduates. The percentages of men in the same or closely associated fields are shown by the following figures:

PERCENTAGES OF GRADUATES IN THE SAME FIELDS AND THOSE CLOSELY ASSOCIATED WITH THEIR COLLEGE COURSES.

	Graduates of 1922, '23 and '24.	Graduates of 1919 and Earlier Classes.	Both Groups.
Civil Engineers	85.8	71.2	73.5
Electrical Engineers	80.3	56.7	70.6
Mining Engineers	74.6	50.0	65.4
Mechanical Engineers	62.0	62.5	62.1
Chemical Engineers	61.2	60.7	61.0

Comparing the several branches of engineering, the ratio of the number of older graduates remaining in the same or closely associated lines of work, to the number of recent graduates so remaining, is

For Mechanical Engineers	1.01
Chemical Engineers	0.99
Civil Engineers	0.83
Electrical Engineers	0.71
Mining Engineers	0.67

From this it appears that mining engineering has the least security of hold on its graduates. It is not clear what the comparatively small proportion of recent graduates as compared with older graduates remaining in mechanical and chemical engineering may mean; whether there is temporarily a smaller demand in those fields or a larger demand in others.

Types of Positions Occupied.—Tables 4 and 5 and Fig. 2 show the types of positions, or kinds of work, of engineering graduates. Of the recent graduates, 59.6 per cent are in technical engineering, 11.5 per cent are in research and teaching, 16.2 per cent in sales and administrative work, and 12.7 per cent in clerical, manual or miscellaneous types of work. Of the older graduates, 22.5 per cent are in strictly technical work, 10.1 per cent in research and teaching (note the slight change from recent graduates), 63.9 per cent are in ownership, executive, and administrative work including sales, and 3.5 per cent are in clerical and miscellaneous types of employment. These figures show a healthy progression through technical work toward the responsibilities of management, and also indicate that engineering courses fit graduates to a satisfactory degree for the responsibilities of the direction of American industry. Fig. 2 shows the above tendencies quite strikingly.

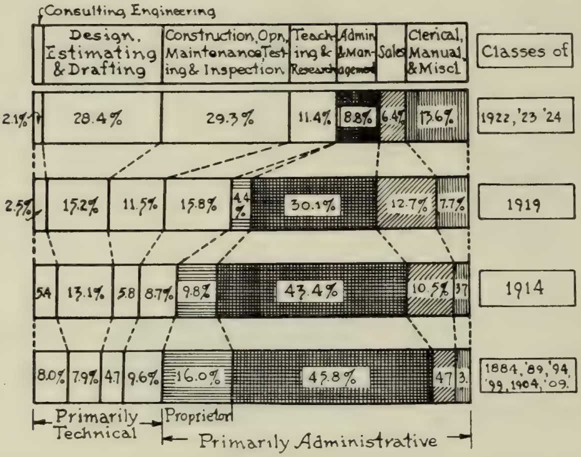

FIG. 2. Progressive trend of engineering graduates to managerial duties.

Earnings of Graduates.—Tables 6 and 7 and Fig. 3 give the earnings of engineering graduates as determined from figures supplied by the graduates themselves. It is to be remembered that data upon which the figures and tables are based were supplied by approximately one-half of those canvassed in the recent classes and approximately one-third in the older classes. Question may therefore be raised as to the accuracy of the figures. In order to determine their accuracy as nearly as possible, a number of checks were applied. One was the tabulation of a proportion of the replies and a comparison of the results with those for all replies. No significant differences were found, figures for all of the men replying being almost exactly the same as those for the first random 25 per cent. Figures submitted by colleges which obtained a high percentage of responses were then compared with those which obtained a small percentage. Again no significant differences

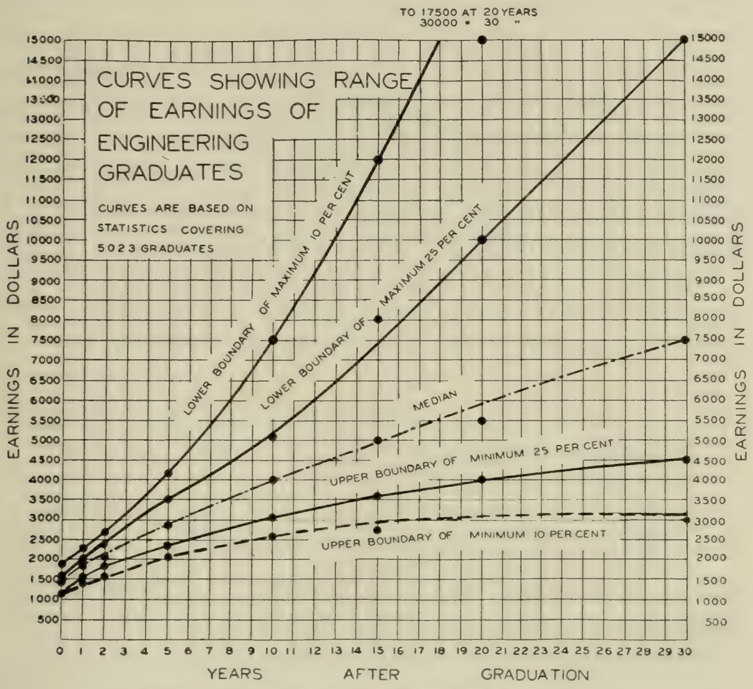

FIG. 3. Earnings of engineering graduates.

were found, though the percentage of responses varied from as many as sixty-six to as few as twenty. Finally the results of this study were compared with a study of earnings made by Eta Kappa Nu, an honorary society of electrical engineering students and graduates (See BULLETIN No. 8 of this series). In the fraternity's study, approximately sixty-three per cent of those canvassed supplied data. The results of the two studies agree quite closely as to median and average curves. The distributions of earnings are also found to follow probability curves. In view of all available information it seems probable that the figures given herein are substantially reliable and give a fair picture of the earnings of engineering graduates.

Beginning Salaries.—Table 6 shows a steady increase in salaries for the first year after graduation. It is interesting to compare the larger incomes of recent years with the decreased value of the dollar. For example, if we compare the median beginning salary of the class of 1914 or $800, with that of the class of 1924 or $1,476, on the basis of a sixty-three cent dollar in 1924 to par in 1914, we find that the present graduate is more than holding his own, the value of the 1914 salary on the basis of 1924 money values being about $1,270.

The earnings of recent graduates seem to increase steadily and satisfactorily, their progress being approximately $300 per year in annual salary, as shown by the following table:

	Median Earnings of Recent Graduates	
	Per Month.	Per Year.
Immediately after graduation	$123	$1,476
Six months after graduation	133	1,596
Twelve months after graduation	150	1,800
Twenty-four months after graduation	175	2,100

The progress of older graduates seems fair, though the rate of increase of the early years is not maintained.

There do not seem to be extreme variations between earnings of graduates of different institutions, certainly none greater than would be expected due to varying economic conditions of different parts of the country. Maximum and minimum median salaries of graduates at the beginning of 1925 reported by the various institutions are:

Class of 1924,	minimum	$110 per month,
	maximum	175 per month,
Class of 1923,	minimum	130 per month,
	maximum	219 per month,
Class of 1922,	minimum	140 per month,
	maximum	250 per month.

The Placement Process.—Tables 8, 9, 10, and 11 and Figs. 4, 5, and 6 give data and views obtained from recent graduates which bear upon the problems of placement and early adjustment in industry.

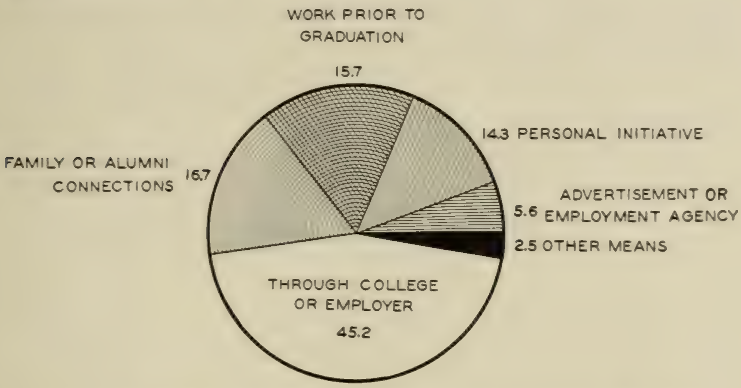

FIG. 4. Means through which engineering graduates obtain first positions.

Graduates in engineering obtained their first positions in the following manner: Through a teacher or other official of the colleges, 24.7 per cent; through the solicitation of an employer, 20.5 per cent; through work done prior to graduation, 15.7 per cent; through personal solicitation of employer by the graduates, 14.3 per cent; through family connections, 9.9 per cent; through alumni of the colleges, 6.8 per cent; through advertisement or employment agencies, 5.6 per cent; and by other means, 2.5 per cent. It will be noted that but 45.2 per cent of all the graduates obtained their first positions through the organized efforts of the colleges or employers.

Choice of First Position.—The reasons given by the graduates for their choice of first positions are as follows: Because the work was in direct line of their college course or closely associated with it, 49.5 per cent; apparent good opportunities, 25.8 per cent; only job available, 9.7 per cent; desired location, 8.7 per cent; good salary, 3.6 per cent; other reasons, 2.7 per cent. The desire for the right sort of experience or of opportunity was evidently of far more influence than all others, being 75.3 per cent of the total. Contrary to general impression, perhaps, the question of salary was ostensibly a very minor factor. The figures show an excellent demand for men of engineering training.

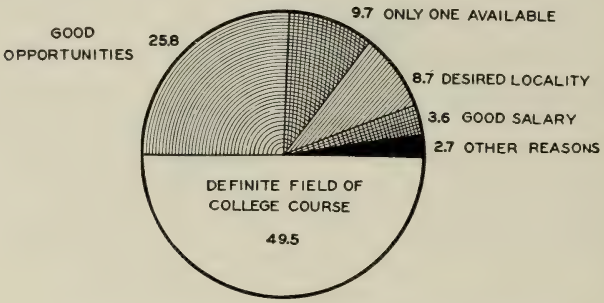

FIG. 5. Reasons for choice of first positions.

Shifting of Positions in Early Years.—The above relates to the first positions held. It is found that there is a very considerable shifting about from job to job among the recent graduates. Of the graduates of 1922, 57.0 per cent held two

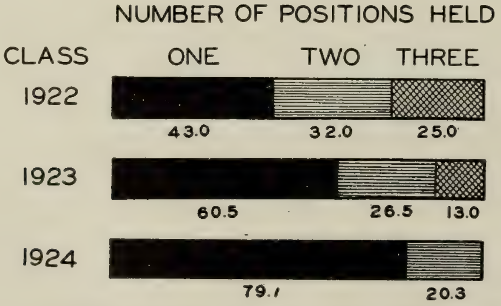

FIG. 6. Number of positions held since graduation.

or more positions and 25.0 per cent held three or more positions in the first two and one-half years after graduation. Of the class of 1923, 39.5 per cent similarly held two or more positions, and 13.0 per cent held three or more in the first one and one-half years after graduation. Even in a class graduating as recently as 1924, about one-fifth held two or more positions in the first six months after graduation. These figures show an unwise choice of first positions in altogether too high a percentage of cases. Of the graduates who do change positions many do not remain long enough in the first job to gain much experience or even to obtain a clear conception of its ultimate possibilities. An undue amount of time is wasted by these graduates before they are established in their life's work. This high percentage of turnover among recent graduates could certainly have been reduced, it is believed, by more effective vocational guidance in the colleges.

It is one of the encouraging signs of the times that some institutions have realized this need and are meeting it through the introduction of personnel systems and the selection of personal advisers, either from among the faculty or individuals specially designated for the work. It is also significant that some colleges are providing means of giving to prospective graduates adequate information as to the various lines of work open to them. It must be admitted, however, that only a fair start has been made. It is also probably true that the methods employed by the industries in the selection of graduates are not yet as completely organized and scientific as they ought to be. Perhaps this is partly a problem of coordination of industrial and collegiate personnel methods.

In spite of the comparatively poor start made by many graduates, it is gratifying to note that 77 per cent express themselves as satisfied with their present jobs, and 81 per cent as satisfied with their prospects, but even more important, that 95 per cent of the graduates express a definite liking for engineering work and more of them, 98 per cent, feel that they made no mistake in taking an engineering course.

B. The Effectiveness of Engineering Courses

General Estimate of Effectiveness.—Tables 12 to 15 inclusive and Figs. 7 to 9 inclusive give the opinions of older graduates on a number of matters relating to the quality and effectiveness of the courses which they pursued in college.

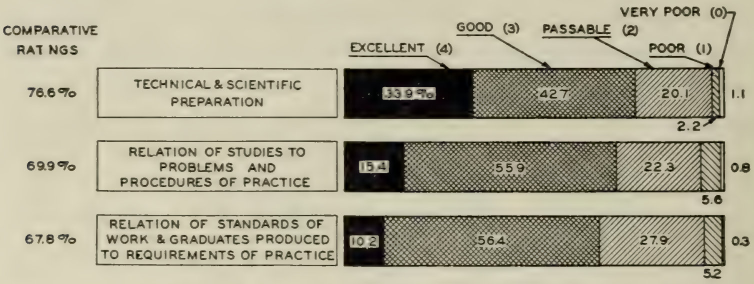

Fig. 7. Opinions of graduates as to effectiveness of engineering colleges.

Table 12 and Fig. 7 seem to indicate that graduates in general feel satisfied with their college courses. Over three-quarters believe that the technical and scientific preparation which they received for their life work was either good or excellent. About seventy per cent rate the relationship between the engineering subjects as taught and the problems of engineering practice equal highly, and approximately two-thirds feel that the standards of work done and of graduates produced by engineering colleges are either good or excellent.

Table 13 and Fig. 8 give some interesting indications of the manner and extent to which graduates believe their college experiences are valuable to them. The comparative scores shown in Fig. 8 were obtained by assigning arbitrary values of 0 to the designation "none," 1 to "little," 2 to "moderate," 3 to "great" and 4 to "very great." These values were multiplied by the percentages of replies which indicated each of them and the sum was then divided by the maximum assigned value, 4. The results give a rough indication of the comparative values which graduates assign to each of the several points and also indicate the order in which graduates believe their experiences have been valuable. It will be noted that they rank *knowledge of fundamental principles of science* first, following this with *discipline in methods of thinking and habits of work,* and that they place *training in craftsmanship* last.

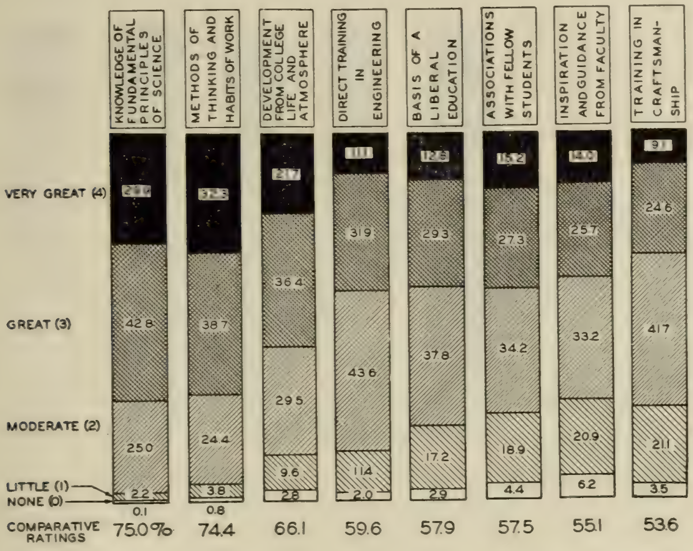

FIG. 8. Opinions of graduates as to value of college experiences.

Results Produced and Qualities Sought.—Tables 14 and 15 and Fig. 9 give the opinions of older graduates on the extent to which engineering courses are likely to produce certain results and also upon the qualities which they seek in younger engineers whom they employ. An arbitrary system of rating the results has been adopted similar to that explained above, the results being shown in Fig. 9. It will be noted—as might have been expected—that good character and qualities of leadership take first rank, and that graduates feel that development of qualities of leadership and powers of initiative and originality come last in rating the results of engineering courses.

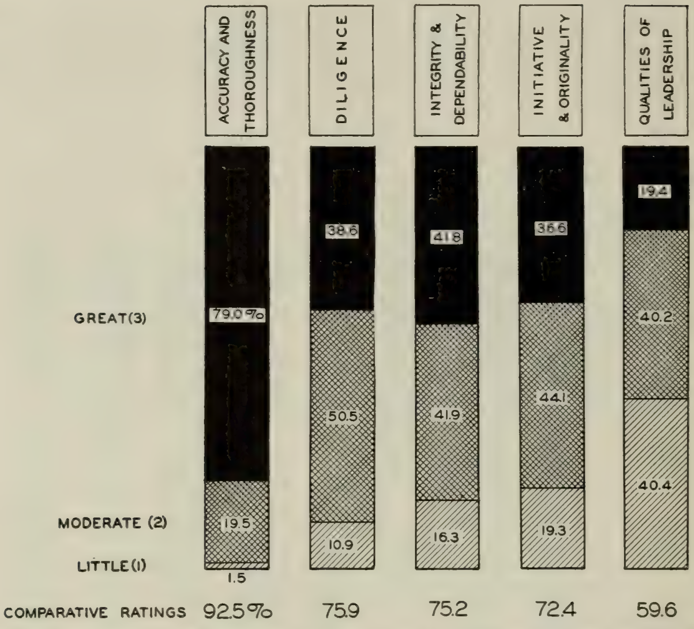

FIG. 9. Opinions of graduates as to extent engineering courses tend to develop certain characteristics.

Purposes of Engineering Curricula.—Opinions of graduates as to the objectives of engineering courses were expressed as follows:

To train broadly for the general needs of industry	20.6%
To train for the specific needs of specialized divisions of engineering practice	11.9%
To provide the former type of training for the majority and the latter for those who desire it	67.5%

The fact that so many hold this last idea indicates the need for serious effort to determine what provisions engineering colleges may make to that end.

The importance assigned by graduates to the various general divisions of curricula are indicated by the following tabulation. In this table a score of 1 would indicate that all graduates assigned a given division first place, and a score of 4 would indicate that all had assigned it last place. The weighted scores were obtained by adding the various rankings and dividing by the number of individuals who expressed opinions.

	Weighted Scores
Scientific subjects	1.70
Technical subjects	1.80
Economic subjects	2.94
Cultural subjects	3.32

These scorings are interesting and significant. It is evident, for one thing, that our graduates believe that engineering courses should continue to be essentially scientific and technical in character since they give much greater weight to these divisions than to economic and cultural subjects. The fact that economic subjects are placed before cultural subjects is also significant since at present the latter are given considerably greater weight in the curriculum. Our graduates evidently feel that the engineer needs general cultural education, just as he needs good character, but that it is the scientific and technical part of his education which prepares him for engineering rather than for something else.

Value of Cultural Studies.—In connection with the matter of cultural studies in the engineering curriculum, recent graduates were asked to indicate by checking against a list of five items, the value which they assigned to the cultural studies which they pursued in college. The results were as indicated by the percentage of replies opposite each of the five following designations:

"Indispensable to my intellectual development"	24.5%
Considerable	32.5%
Sufficient to warrant time spent	28.6%
Not proportionate to time spent	4.0%
Negligible	10.4%

It is noteworthy that nearly sixty per cent indicated their belief that cultural studies were of "considerable" or greater value to them.

Modifications Suggested by Graduates.—Tables 16, 17, and 18 and Fig. 10 give the opinions of recent graduates on changes which might profitably be made in engineering curricula. The most outstanding criticism is the lack of training in business and economic subjects. Next in importance is the evident belief that more attention should be given to English. It is significant to note that only about one graduate in five replied to the question as to subjects considered unessential. Of those who did reply, more indicated modern foreign languages than any other one subject, with shop work second. It must be remembered, in this connection, that graduates of all courses expressed themselves and it is possible that those who indicated shop work as unessential were students of courses in which shop work is of minor importance.

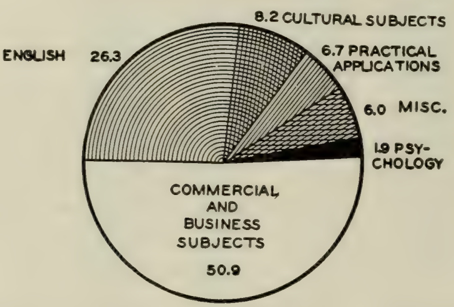

Fig. 10. Opinions of recent graduates as to important omissions from engineering courses.

Selected Comments of Graduates.—Each of the graduates was asked to contribute spontaneous suggestions as to desirable changes in engineering curricula. Many of these replies are interesting and some are valuable. A few have been selected as samples and appear below. No attempt has been made to choose the best answers, but rather to select typical ones.

"I consider that the field of greatest service of the University is in *vocational guidance* based on a thorough and scientific knowledge of vocational psychology. To me, the greatest of all tragedies is 'the square peg in the round hole.' I know, for I have been one. The greatest work a college of engineering can do, in my estimation, is to study the man, his *inclinations* and native abilities and then start him right. A right start is a fortune in itself."

"Students should be given more explicit information in regard to the different branches of engineering. For example, I never knew the many departments in which an engineer may be employed until it was explained to me by representatives of concerns doing college recruiting. This information, coming as late as it did, caused me to make a hasty and unwise decision in choosing my work."

"The four-year engineering course is too short to accomplish all it purposes to accomplish. My course endeavored to give me a cultural background and also to fit me equally to serve in any one of the several branches of engineering. The course should be at least five years and during the last two years a man should be allowed to specialize in his chosen line, while gaining only a general knowledge of the other branches of the profession."

"There is too much work to cover in the time given, there is not enough opportunity given for self expression and development; too much emphasis is placed on grades given for academic information and not enough on character and application. Industry pays for character and the ability to accomplish and create."

"The theoretical and practical sides of engineering should be more closely linked in the college course (instead of studying theory then later on finding out what it's all about)."

"The course offered no advancement in the appreciation of the finer and 'cultural' things of life. Sufficient training in economics and administration was lacking. There was not sufficient personal contact between the student and the faculty."

"While I do not think college is the place to get practical experience, but rather to get a good technical foundation, I do think few of the instructors have had enough contact with industrial work to give the students a send off with the right point of view to fit in readily in industrial positions."

C. CONTINUATION OF STUDIES AFTER GRADUATION

Proportion of Graduates Continuing Their Studies.—The data on this subject are enlightening and seem to give evidence of a considerable carrying on of the intellectual stimulus received in college. Tables 19 and 20 give information obtained from recent and older graduates in this connection. Among the older graduates a gratifying number, 13.7 per cent, continued graduate work in a college or university. (This figure is confirmed by statistics compiled by the United States Bureau of Education.) It is also significant to note that nearly one-quarter continued their education through extension, correspondence, or similar courses, or through regular courses of study given or supervised by employers. Assuming that there are few duplications among the men indicating these methods of continuing their education, it is evident that nearly three-eighths of those who answered the questionnaire continued their education through regular courses of study. The proportion who continued study more or less systematically as the nature of their work demanded, or who otherwise pursued some course of study under their own regulation, is over eighty per cent. In fact only about one-tenth of the graduates state that they have not studied along technical lines after leaving college. The participation of the colleges themselves in this work is small, however, being represented almost entirely by the group of men who pursued resident, graduate courses.

Educational Efforts of Recent Graduates.—Of the recent graduates the following facts are given: Approximately three-quarters of their positions were such as to require study; 56.6 per cent have studied along lines of their college courses, while 26.8 per cent have studied along lines not closely connected with their college work (a total of 83.4 per cent who have studied during the first two and one-half years after graduation). Over one-fourth reported that they have studied under the supervision of their employers, while nearly sixty per cent replied that they have studied independently of their employers' supervision and direction. A substantial and gratifying number, approximately forty-three per cent, reported that they had continued their interest in and study of cultural subjects.

In this connection it may be noted that the recent graduates were asked to state those subjects of a cultural nature in which they had continued interest after leaving college.

No definition of the word "cultural" was given, but each graduate listed his subjects of interest spontaneously. Economics, accounting, law, business administration, and other subjects connected with the business aspects of industry were mentioned most frequently. English literature, public speaking, and related subjects came next in order. Then followed history, psychology, philosophy, political science, sociology, music, the fine arts, languages, various sciences, and a miscellaneous group including journalism, education and others. Over half of the mentions, however, were confined to commerce and business subjects and to English. This strong preponderance, taken in connection with answers to other questions, indicates that graduates feel very strongly that engineering curricula are deficient in the time and emphasis devoted to these subjects.

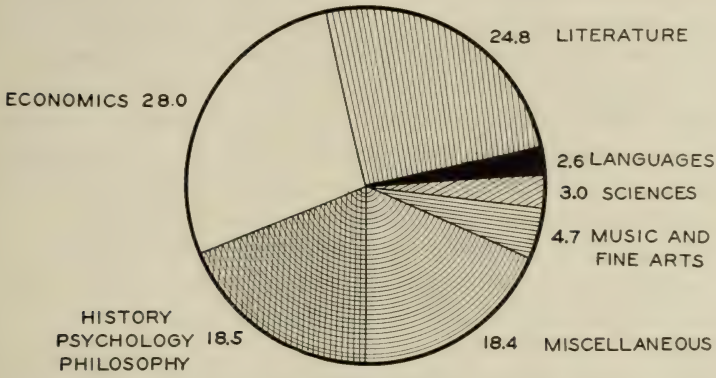

FIG. 11. Types of cultural interests of engineering graduates.

Significant Points.—The most significant points in the matter of the continuation of study by graduates seem to be, first, the large proportion who have continued their education, and second, the relatively small participation in this work by the colleges themselves. It is believed that engineering colleges may well give serious consideration to means of exercising greater influence over the intellectual life of their graduates and of guiding and directing their studies in such a way as to insure a maximum result for the time and energy expended. This matter will be discussed more fully later.

D. Records of Non-Graduates

Data on Former Students.—As previously stated, the evidence on students who did not graduate is not sufficiently complete to warrant more than general observations; in fact, it is doubtful whether the group canvassed is representative of the general group of engineering students who do not complete their courses. For one thing, the average time these students remained in college was 3.7 semesters or 1.85 academic years. This is rather longer than the length of time spent in college by the average student who does not graduate. It seems probable that the questionnaire was answered by students who have maintained a greater interest in their college than the average non-graduating student has.

Tables 21 to 24 inclusive give most of the significant material gathered from the non-graduates who replied to the questionnaire. In studying these results, it should be remembered that other evidence not tabulated indicates that the non-graduating students enjoyed as good health as students who do graduate and, furthermore, that the amount of time which they devoted to college activities and self-support was, if anything, less than the time similarly devoted by students who do graduate. These factors, therefore, appear not to have had an abnormal influence on the scholastic careers of these men.

Reasons for Leaving College.—The predominant reasons for leaving college, or at least for leaving engineering, are scholastic failure, lack of interest, and voluntary change of course, these reasons combined being the cause of 42.6 per cent of the withdrawals. These students obviously were misplaced either because of lack of ability, aptitude, or interest. Financial difficulty was stated as the chief reason in 24.3 per cent of the cases. War service was cited by 11.7 per cent, this being, of course, an unusual reason. Other reasons were health, 8 per cent, change in status of family, 6.4 per cent, and miscellaneous reasons, 7 per cent. It is rather interesting to note that the percentage of students who reported financial difficulty as the reason for leaving college, 24.3 per cent, is precisely the same as the number who reported complete dependence upon self-support during college, though it does not follow that these figures represent the same individuals. It is difficult to reconcile the statements that financial difficulty was a chief reason for leaving college in so many cases, since the percentage of self-supporting students, as before stated, is no greater in this special group than it is among engineering students in general. It may be that the non-graduating students have unconsciously overemphasized this factor.

Of the causes of scholastic difficulty into which detailed inquiry was made, it appears that 55.6 per cent of the men acknowledged their difficulty to have been either poor preparation, carelessness or neglect, or lack of interest. It may be noted that figures obtained from college records indicate that 69.4 per cent of scholastic failures are attributable to these causes. The difference between these two figures, while not large, may be due to the difference in point of view of the two groups, the students on the one hand and the college authorities on the other. The blame was put by the former students on the school or on the teachers in 23.2 per cent of the cases. The cause of the failure of 10 per cent more was given as the outside demands on their time, such as necessity for self-support. Contrary to the usual opinion, at least in the minds of the non-graduates themselves, social diversions, athletics, and college activities played a very minor part in the failures.

PART II. CONCLUSIONS AND RECOMMENDATIONS OF THE COMMITTEE

It is recognized that the field of study in connection with problems of engineering graduates is a very broad one. It is not within the bounds of practicability to consider all problems within that field at present. Attention has therefore been concentrated upon the following specific issues which it is believed should receive the early and earnest attention of engineering colleges:

A. Guidance of graduates in choosing fields of work and first positions.

B. Assistance in the continuation of study after leaving college.

A. Guidance of Graduates in Choosing Fields of Work and First Positions

Evidences of the Need.—"I consider that the field of greatest service of a university is in *vocational guidance* based on a thorough and scientific understanding of vocational psychology. To me the greatest of all tragedies is 'the square peg in the round hole.' I know for I have been one. The greatest work that a college of engineering can do, in my estimation, is to study the man, his inclinations and native abilities, and start him right. A right start is a fortune in itself."

This answer to one of the questions put to engineering graduates is expressive because of its terseness. It has been widely quoted and while the words are those of only one man, they seem to express a thought in the minds of a great many graduates. The very considerable shifting from position to position during the first year or so after graduation is evidence of the genuine need for constructive work in this field. While a certain amount of shifting is inevitable and in some cases desirable, it seems probable that these figures show that an undue amount of time is wasted by too large a proportion of graduates before getting definitely settled. Evidently too many graduates choose positions for which they are not fitted. Apparently engineering colleges and the industries, jointly, must contribute to the solution of this problem.

Problem of Choice Among Functional Types of Activity.—The question of what to do with an engineering education after it has been obtained is just as important as the decision to go to college to acquire it. As the senior approaches the time to leave college and get started in his profession, he finds himself confronted with the problem of making a choice among types of work described in somewhat different terms from those to which he has been accustomed. It is no longer sufficient for him to say that he will follow electrical engineering or mechanical engineering. He finds the emphasis of prospective employers based to a considerable extent upon an entirely different classification of engineering work. He finds, for example, that industry is less inclined to emphasize differences between electrical engineering and mechanical engineering than it is to emphasize the distinction between the engineering of research or design and the engineering of operation or management. The prospective graduate, therefore, finds himself called upon to make a decision as to which of the *several engineering functions* he will follow. Engineering curricula are not differentiated in accordance with these functional divisions, nor, in general, is any particular effort made to develop students as research engineers, design engineers, operating engineers or sales engineers. In fact, the graduate has had little opportunity in his college course to obtain a clear conception of the several functional divisions of engineering open to him.

It has been suggested that curricula might well be differentiated in accordance with these functional divisions. (See ''Engineering Courses for the Functional rather than the Industrial Divisions of Engineering'' by Edward Bennett; ENGINEERING EDUCATION, June 1924). If this were done one of the ends served would be effectively to orient the student to one particular functional division and doubtless also to acquaint him with the characteristics of others. This proposal is of such importance, however, as to require greater space for adequate treatment than is here afforded. These comments will therefore be confined to curricula and methods as found at present.

The Normal Path of Progress.—Detailed figures showing the distribution of engineering graduates among the several fields of design, operation and maintenance, research, sales, management, etc., are given in Tables 4 and 5. These figures show not only the various lines of work and functional divisions of engineering into which graduates go upon leaving college, but also the progressive trends from some types of activity to others. It is shown clearly, for example, that a majority of the graduates are employed in their earlier years in the more definitely technical types of work while the older graduates are engaged in work which is primarily of an administrative nature.

It is obvious that this should be the normal path for engineering graduates to follow in their progress to responsible positions. It is doubtful, however, if the prospective graduate has any clear conception of this and other important matters bearing upon his future. In particular, as above stated, it is doubtful if he visualizes the differences between the several functional divisions previously mentioned. Probably in a majority of cases the student has given little serious study to the particular type of activity for which he is best suited, in fact he generally lacks the knowledge of the situation upon which to base such study.

Summary of the Problem and of Means of Betterment.—The problem of the vocational guidance of engineering graduates seems, therefore, to resolve itself into one of finding ways and means of giving the prospective graduate a conception of the functional or vocational arrangement of engineering work as it actually exists and of providing means whereby he may be brought to think of himself, his instincts, tastes, personality, ability, etc., in terms of the requirements for successful work in these several functions.

Some of the possible means of accomplishing this objective embrace the following:

A. The presentation of a well organized series of lectures to all seniors in which industry would cooperate by supplying speakers competent to give a clear picture of the nature of the work and opportunities in their respective fields. One lecture of such a series might well include the facts as to lines of employment of recent and older graduates presented herein. These data lend themselves to diagrammatic presentation and can be shown by lantern slides.

B. Better organization of the time and efforts of employment representatives when visiting colleges so as to conflict least with classes during the recruiting periods. Assistance might also be given the representatives in the determination of those seniors best adapted to the work in each specific industry.

C. In order that all possible information may be available in aiding both the graduate and the industry in wise selection, it would be advisable for colleges to maintain personnel record of all their students. These would be of considerable educational value and would be particularly helpful in connection with employment. A representative of industry indicates that employers would be interested in the following data:

1. To identify the student.
    - (*a*) Name.
    - (*b*) Home address.
    - (*c*) College address and telephone number.
    - (*d*) Age, height and weight.
2. To indicate the influence of heredity and home environment.
    - (*a*) Parents' education, occupation and nationality.
    - (*b*) Church affiliations.
3. To indicate educational attainment and grade of mentality.
    - (*a*) Preparatory or high school scholastic records and name of school.
    - (*b*) Recommendation of preparatory or high school principal before entering college.
    - (*c*) College scholastic record including all honors and special recognitions.
    - (*d*) Name of intelligence test and rating of the student (if tests are given).
    - (*e*) Chronological record of personal conferences with the student including reasons therefore, recommendations made, and if possible, the effect.
4. To indicate physical condition and capacity for leadership.
    - (*a*) Record of physical examinations. Defects and doctors' recommendations, both upon entering college and at the beginning of the senior year.
    - (*b*) Record of participation in college activities.
    - (*c*) Record of athletic activities.
    - (*d*) R. O. T. C. or military record.
    - (*e*) Membership in professional societies.
5. To indicate previous experience and degree of dependence.
    - (*a*) Positions held, name of employer, type of work, with dates.
    - (*b*) Portion of college expenses earned.

6. To indicate effect of the above influences in the development of personal characteristics. Ratings by the dean, department head, or individual members of the faculty on—
    - (*a*) Personal appearance.
    - (*b*) Culture.
    - (*c*) Mentality.
    - (*d*) Leadership.
    - (*e*) Reliability.
    - (*f*) Capacity for growth.
7. To indicate the student's aptitude for particular fields of endeavor.
    - (*a*) A statement from the student as to what he feels he would like to do and could be most successful in, giving reasons wherever possible.
    - (*b*) Statement of the dean or department head of his opinion as to what field of endeavor the student should enter, with reasons.

B. Continuation of Education after Leaving College

Why Needed?—As the purpose of engineering education is to give a training in certain fundamental principles and methods and some acquaintance with their application to problems of practice, the student naturally has very little opportunity in the undergraduate program to deal with actual engineering problems and acquires little or no real conception either of engineering as a whole or of any of its divisions. The first two years after graduation may be likened to the period of internship of the young physician. Young engineers, however, do not spend their probationary period under conditions of uniformly close supervision, but rather under the widest diversity of conditions. That this should be the case seems entirely reasonable and accords with the tremendous breadth of the engineering field, the great multiplicity of its technical divisions, and the range of functional activities of engineers.

Recognizing that a college course does not complete an engineering education, industrial concerns which employ large numbers of recent graduates have instituted systematic postscholastic training programs with the purpose of initiation to engineering work and of orientation to the industry itself. A considerable number of graduates enroll in these courses as post-graduate students for the purpose of further training; some without intending to remain permanently in the employing organization.

It is hardly thinkable that the colleges would desire to supersede these efforts, essentially recognized as an industrial responsibility in that the industry's efforts are largely directed toward the training of employees for its particular work. It must be remembered, however, that such courses are practicable only as activities of the larger organizations. Futhermore, they cannot provide for more than a minority of graduates and they cannot provide equally for the graduates of all courses.

That the graduates themselves realize that their college courses are not designed to provide a complete engineering education is apparent from the data presented herein. Referring to the tables, it will be found that only a small fraction of the graduates replying stated that they had not more or less systematically pursued some course of study. It is also to be noted that about one-fourth of the graduates replied that such study had been advised or supervised by employers and that three-fourths of the positions occupied were such as to require a continuation of education begun in college. It may also be pertinent to mention the considerable enrollment of engineering graduates in correspondence courses, particularly those of a general business character.

Responsibilities of the Colleges.—All of the foregoing is mentioned to substantiate the belief that the time is ripe for the colleges to consider ways and means of assisting graduates in educational work after leaving college. It is worthy of note that in the year 1925–26 upwards of 1,100 students were pursuing graduate courses in engineering, this number representing about one-eighth of the number receiving first degrees in the previous year. It is gratifying that this number is so large and it is probable that provision for such work should be even more extensive, provided always that it is kept on a high plane and that enthusiasm does not lead to the establishment of graduate courses without adequate teaching personnel and facilities. The mere provision of graduate courses, however, does not entirely meet the situation. As previously stated, it is both necessary and desirable that a majority of graduates should begin productive work in actual practice immediately upon completion of their undergraduate courses.

Methods of Meeting the Need.—There appears to be a distinct, though undeveloped field of opportunity for the colleges to assist these young men in extending their education. As possible means to these ends, the following suggestions are offered:

1. The colleges may make well-outlined reading courses available to such graduates as apply for them.
2. Certain institutions, if properly manned and organized, may offer correspondence courses. Subjects such as contracts and specifications; industrial organization and planning; commercial methods, organizations and law; cost accounting; and financial methods lend themselves to instruction by this means.
3. In certain cases extension courses such as those given by the University of Wisconsin for graduate students in Milwaukee may be set up in industrial centers in which graduates in particular fields can confer with representatives of the institutions at regular intervals. Post-scholastic courses of the following types may be offered:
    - (*a*) Advanced work of the kind given in post-graduate residence courses in mathematics, physics and engineering subjects.
    - (*b*) Courses dealing with recent developments, designed to enable graduates to keep abreast of scientific progress.
    - (*c*) Seminars for the discussion in the light of fundamental theory of
        - (1) Allied research problems,
        - (2) Design problems,
        - (3) Operating problems.

4. The engineering colleges may individually undertake to furnish advisory services to alumni and other engineers in the vicinity of the colleges to assist in such matters as:
    - (*a*) Recommended reading courses.
    - (*b*) Supplying of information as to educational facilities available in the community in which the graduate is located.
    - (*c*) Advice and suggestions relative to engineering problems of the kind rendered to students in residence who are engaged in thesis projects.

It is recognized that there are limitations imposed by the budget and that different institutions will find different methods possible or serviceable. The present purpose, however, is to call attention to the opportunity and need for work among the graduates and to affirm the belief that no other undeveloped activity of the engineering colleges offers larger possibilities for increased service.

PART III. TABULAR SUMMARY OF DATA

(Based on 3,933 graduates of 43 institutions in the classes of 1922, 1923, and 1924; 2,336 graduates of 34 institutions in the classes of 1919, 1914, and earlier, at five year intervals; and 721 non-graduate former students of 14 institutions and of the classes of 1924, 1919, 1914, 1909, and 1904.)

1. Fields of Work of Older Graduates.

		Classes of					Totals.
		1919.	1914.	1904, 1909.	1894, 1899.	1884, 1889.	
Industrial	No.	158	276	363	164	24	985
	%	*35.8*	*45.9*	*43.5*	*40.7*	*23.8*	*41.3*
Commercial	No.	80	86	136	68	17	387
	%	*18.2*	*14.3*	*16.3*	*16.8*	*16.8*	*16.3*
Financial	No.	35	20	39	12	2	108
	%	*7.9*	*3.3*	*4.7*	*3.0*	*2.0*	*4.5*
Professional	No.	114	136	195	108	42	595
	%	*25.9*	*22.7*	*23.3*	*26.8*	*41.6*	*25.0*
Governmental—Others	No.	54	83	102	51	16	306
	%	*12.2*	*13.8*	*12.2*	*12.7*	*15.8*	*12.9*

2. RELATIONSHIP OF FIELDS OF WORK OF RECENT GRADUATES TO COLLEGE COURSES.

Courses Graduated From.		Present Fields of Work.				Totals.
		Engineering.			Non-Engineering Field.	
		Same Field.	Closely Associated Field.	Unassociated Field.		
Chemical Engineering	No.	210	47	70	93	420
	%	*50.0*	*11.2*	*16.6*	*22.2*	
Civil Engineering	No.	609	18	59	45	731
	%	*83.3*	*2.5*	*8.1*	*6.1*	
Electrical Engineering	No.	672	44	85	91	892
	%	*75.3*	*5.0*	*9.5*	*10.2*	
Mechanical Engineering	No.	515	89	238	131	973
	%	*52.9*	*9.1*	*24.5*	*13.5*	
Mining Engineering	No.	96	33	23	21	173
	%	*55.5*	*19.1*	*13.3*	*12.1*	
Totals	No.	2,102	231	475	381	3,189
	%	*66.0*	*7.2*	*14.9*	*11.9*	

3. Relationship of Fields of Work of Older Graduates to College Courses.

Courses Graduated From.		Present Fields of Work.				Totals.
		Engineering.			Non-Engineering Field.	
		Same Field.	Closely Associated Field.	Unassociated Field.		
Chemical Engineering	No.	69	16	33	22	140
	%	*49.3*	*11.4*	*23.6*	*15.7*	
Civil Engineering	No.	494	39	90	126	749
	%	*66.0*	*5.2*	*12.0*	*16.8*	
Electrical Engineering	No.	309	41	133	134	617
	%	*50.0*	*6.7*	*21.6*	*21.7*	
Mechanical Engineering	No.	292	63	104	109	568
	%	*51.4*	*11.1*	*18.3*	*19.2*	
Mining Engineering	No.	44	8	28	24	104
	%	*42.3*	*7.7*	*26.9*	*23.1*	
Totals	No.	1,208	167	388	415	2,178
	%	*55.5*	*7.7*	*17.8*	*19.0*	

4. Types of Positions Held by Recent Graduates as of January 1, 1925.

(Secondary as well as primary aspects of positions are included.)

	Number.	Per Cent.	
Construction	642	10.1	
Design	681	10.7	
Testing	662	10.4	
Estimating	577	8.9	
Drafting	519	8.2	
Operation and Maintenance	580	9.1	
Consulting Engineering	138	2.2	
		—	59.6
Research	482	7.7	
Teaching	238	3.8	
		—	11.5
Administration	605	9.5	
Sales	428	6.7	
		—	16.2
Clerical	338	5.3	
Manual	121	1.9	
		—	7.2
Others	351	5.5	
		—	5.5
			100.0

5. TYPES OF POSITIONS OF OLDER GRADUATES.

		Classes.										Totals.
		1919.		1914.		1904 and 1909.		1894 and 1899.		1884 and 1889.		
Consulting Engineering	No.	12		34		55		44		18		163
	%	*2.7*		*5.4*		*6.5*		*10.2*		*18.8*		*6.7*
Design	No.	37		44		47		24		5		157
	%	*8.4*		*7.0*		*5.6*		*5.6*		*5.2*		*6.4*
Estimating	No.	20		21		11		5		3		60
	%	*4.5*		*3.4*		*1.3*		*1.2*		*3.1*		*2.5*
Drafting	No.	10		6		4		5				25
	%	*2.3*		*1.0*		*0.5*		*1.2*				*1.0*
Operation & Maintenance	No.	20		24		23		22		1		90
	%	*4.5*		*3.8*		*2.7*		*5.1*		*1.0*		*3.7*
Testing & Inspection	No.	28		13		5		5		2		53
	%	*6.4*		*2.1*		*0.6*		*1.2*		*2.1*		*2.2*
			28.8		*22.7*		*17.2*		*24.5*		*30.2*	
Research	No.	30		26		23		18		1		98
	%	*6.8*		*4.2*		*2.7*		*4.2*		*1.0*		*4.0*
Teaching	No.	33		23		61		24		7		148
	%	*7.5*		*3.8*		*7.2*		*5.6*		*7.3*		*6.1*
			14.3		*8.0*		*9.9*		*9.8*		*8.3*	
Owner or Proprietor	No.	24		66		121		81		19		311
	%	*5.5*		*10.5*		*14.4*		*18.8*		*19.8*		*12.8*
Executive & Administrative	No.	54		130		228		113		23		548
	%	*12.3*		*20.7*		*27.1*		*26.3*		*24.0*		*22.5*
Management	No.	25		64		79		32		7		207
	%	*5.7*		*10.2*		*9.4*		*7.4*		*7.3*		*8.5*
Superintendence	No.	53		83		105		33		5		279
	%	*12.0*		*13.2*		*12.5*		*7.7*		*5.2*		*11.5*
Sales	No.	61		71		58		15		4		209
	%	*13.9*		*11.3*		*6.9*		*3.5*		*4.2*		*8.6*
			49.4		*65.9*		*70.3*		*63.7*		*60.5*	
Clerical	No.	6		4		2		1				13
	%	*1.4*		*0.7*		*0.2*		*0.2*				*0.5*
Miscellaneous	No.	26		17		20		8		1		72
	%	*6.1*		*2.7*		*2.4*		*1.8*		*1.0*		*3.0*
			7.5		*3.4*		*2.6*		*2.0*		*1.0*	
Totals		439	*100.0*	626	*100.0*	842	*100.0*	430	*100.0*	96	*100.0*	2,433

6. Earnings of Engineering Graduates.

Class of		Years After Graduation.								
		0.	1.	2.	3.	5.	10.	15.	20.	30.
1924..	Number Reporting....................	1,191								
	Median Annual Earnings...............	*$1,476*								
1923..	Number Reporting....................	1,331	1,218							
	Median Annual Earnings...............	*$1,440*	*$1,800*							
1922..	Number Reporting....................	1,149	1,082	1,023						
	Median Annual Earnings...............	*$1,320*	*$1,800*	*$2,100*						
1919..	Number Reporting....................	319	319	304	274	309				
	Median Annual Earnings...............	*$1,300*	*$1,800*	*$2,000*	*$2,200*	*$2,860*				
1914..	Number Reporting....................	496	475	458	436	444	498			
	Median Annual Earnings...............	*$ 800*	*$1,000*	*$1,200*	*$1,600*	*$2,400*	*$4,000*			
1909..	Number Reporting....................	459	418	414	404	416	422	430		
	Median Annual Earnings...............	*$ 720*	*$ 900*	*$1,200*	*$1,366*	*$1,800*	*$3,000*	*$5,000*		
1904..	Number Reporting....................	243	223	221	212	202	226	216	238	
	Median Annual Earnings...............	*$ 720*	*$ 900*	*$1,200*	*$1,300*	*$1,530*	*$2,500*	*$4,000*	*$5,500*	
1899..	Number Reporting....................	156	126	125	123	125	130	129	147	
	Median Annual Earnings...............	*$ 600*	*$ 800*	*$1,075*	*$1,380*	*$1,600*	*$2,700*	*$4,000*	*$6,000*	
1894..	Number Reporting....................	119	97	96	92	109	102	103	100	116
	Median Annual Earnings...............	*$ 600*	*$ 900*	*$1,000*	*$1,200*	*$1,500*	*$2,400*	*$3,600*	*$5,000*	*$7,500*

7. ANALYSIS OF EARNINGS OF ENGINEERING GRADUATES AS OF JUNE 1, 1924.

Class.	Years Since Graduation.	Number Reporting.	Annual Earnings in Dollars.							
			Minimum.	Limit of Lowest 10%.	Limit of Lowest 25%.	Median.	Limit of Highest 25%.	Limit of Highest 10%.	Maximum.	Most Frequent.
1924	0*	1,191	300	1,200	1,200	1,476	1,560	1,860	4,080	1,200
1923	1	1,218	420	1,404	1,560	1,800	1,980	2,280	5,100	1,800
1922	2	1,023	360	1,560	1,800	2,100	2,400	2,640	9,000	1,800
1919	5	309	1,500	2,100	2,400	2,860	3,500	4,200	25,000	3,000
1914	10	498	1,200	2,600	3,110	4,000	5,100	7,500	50,000	5,000
1909	15	430	1,700	2,700	3,600	5,000	8,000	12,000	49,500	6,000
1904	20	238	1,920	3,290	4,000	5,500	10,000	15,000	90,000	4,000
1894	30	116	1,980	3,000	4,500	7,500	15,000	30,000	100,000	6,000
	Total	5,023								

* Beginning salary.

8. MEANS THROUGH WHICH RECENT GRADUATES OBTAINED FIRST POSITIONS.

(Some graduates indicated more than one means.)

	Number.	Per Cent.	Total Per Cent.
Through the college or a member of the faculty.	959	24.7	
Through solicitation by employer	797	20.5	45.2
Through connection formed or work done before graduation	608	15.7	15.7
Through an advertisement	136	3.5	
Through an employment agency	81	2.1	5.6
Through family connection	386	9.9	
Through alumni of the college	266	6.8	16.7
Through personal solicitation or other endeavor of the graduate	556	14.3	14.3
By other means	97	2.5	2.5
	3,886		100.0

9. REASONS GIVEN BY RECENT GRADUATES FOR CHOICE OF FIRST POSITIONS.

(Some graduates gave more than one reason.)

	Number.	Per Cent.	Total Per Cent.
Position was in definite field of college course	798	19.4	49.5
Position was in general field of college course	1,234	30.1	
Position seemed to offer good opportunities	1,058	25.8	25.8
Position was in desired locality	358	8.7	12.3
Good salary	149	3.6	
Only position available	399	9.7	9.7
Other reasons	113	2.7	2.7
	4,109		100.0

10. NUMBER OF POSITIONS HELD SINCE GRADUATION.

		Classes of			Totals.
		1922.	1923.	1924.	
One position	No.	542	835	988	2,365
	%	*43.0*	*60.5*	*79.7*	*61.0*
Two positions	No.	403	365	252	1,020
	%	*32.0*	*26.5*	*20.3*	*26.3*
Three positions	No.	315	179		494
	%	*25.0*	*13.0*		*12.7*
Total number reporting		1,260	1,379	1,240	3,879

11. REACTIONS OF RECENT GRADUATES TO PRESENT POSITIONS, PROSPECTS, ETC.

	Number.	Per Cent.
Satisfied with positions	2,643	76.9
Dissatisfied with positions	794	23.1
Satisfied with prospects	2,880	81.0
Dissatisfied with prospects	676	19.0
Like engineering work	3,241	95.4
Dislike engineering work	155	4.6
"Glad I studied engineering"	3,564	97.7
"Sorry I studied engineering"	83	2.3

12. OPINIONS OF OLDER GRADUATES AS TO EFFECTIVENESS OF ENGINEERING COURSES.

		Excellent.	Good.	Passable.	Poor.	Very Poor.
Quality of technical and scientific preparation for life work	No.	606	763	360	40	20
	%	*33.9*	*42.7*	*20.1*	*2.2*	*1.1*
Relationship between college subjects and problems and procedures of practice	No.	280	1016	406	101	15
	%	*15.4*	*55.9*	*22.3*	*5.6*	*0.8*
Standards of work done and graduates produced by engineering colleges	No.	182	1001	495	92	6
	%	*10.2*	*56.4*	*27.9*	*5.2*	*0.3*

13. Opinions of Older Graduates as to the Value of their College Experiences.

		Very Great.	Great.	Moderate.	Little.	None.
Knowledge of the fundamental principles of science	No.	616	884	515	46	3
	%	*29.9*	*42.8*	*25.0*	*2.2*	*0.1*
Discipline in methods of thinking and habits of work	No.	662	793	499	77	16
	%	*32.3*	*38.7*	*24.4*	*3.8*	*0.8*
General development derived from college life and atmosphere	No.	393	661	536	175	50
	%	*21.7*	*36.4*	*29.5*	*9.6*	*2.8*
Direct preparation for engineering work	No.	219	630	861	226	39
	%	*11.1*	*31.9*	*43.6*	*11.4*	*2.0*
Acquirement of the basis of a liberal education	No.	247	569	732	334	56
	%	*12.8*	*29.3*	*37.8*	*17.2*	*2.9*
Associations and friendships formed with fellow students	No.	294	530	664	366	85
	%	*15.2*	*27.3*	*34.2*	*18.9*	*4.4*
Inspiration and guidance derived from members of the faculty	No.	274	504	651	411	122
	%	*14.0*	*25.7*	*33.2*	*20.9*	*6.2*
Training in craftsmanship	No.	170	461	783	397	65
	%	*9.1*	*24.6*	*41.7*	*21.1*	*3.5*

14. EXPRESSIONS OF OPINION OF OLDER GRADUATES AS TO THE EXTENT ENGINEERING COURSES ARE LIKELY TO PRODUCE CERTAIN RESULTS.

		Great.	Moderate.	Little.
Develop habits of accuracy and thoroughness	No.	1,335	330	25
	%	*79.0*	*19.5*	*1.5*
Develop diligence	No.	613	801	173
	%	*38.6*	*50.5*	*10.9*
Develop qualities of integrity and dependability	No.	677	679	263
	%	*41.8*	*41.9*	*16.3*
Develop powers of initiative and originality	No.	592	715	312
	%	*36.6*	*44.1*	*19.3*
Develop qualities of leadership	No.	310	644	648
	%	*19.4*	*40.2*	*40.4*

15. QUALITIES SOUGHT BY ENGINEERS IN OTHER ENGINEERS WHOM THEY EMPLOY.

(A score of 1 would indicate that all graduates assigned a given quality first place, and a score of 5 would indicate that all graduates assigned a given quality fifth place. The average scores were obtained by adding the various rankings and dividing by the number of individuals who gave opinions.)

Average Score, or Order of Importance.	Quality.		Relative Weight.		
			Great.	Moderate.	Little.
1.74	Character	No.	806	195	18
		%	*79.1*	*19.1*	*1.8*
2.06	Leadership	No.	782	208	40
		%	*75.9*	*20.2*	*3.9*
3.27	Training in a particular course or specialty	No.	259	513	228
		%	*25.9*	*51.3*	*22.8*
3.31	Physical qualities	No.	229	690	83
		%	*22.9*	*68.8*	*8.3*
4.02	Scholastic record	No.	78	529	372
		%	*8.0*	*54.1*	*37.9*

16. OPINIONS GIVEN BY RECENT GRADUATES AS TO IMPORTANT OMISSIONS FROM THEIR COLLEGE COURSES.

	Number.	Per Cent.	Total Per Cent.
Commercial and business subjects	595	30.9	
Economics, engineering economics	202	10.5	
Business law	59	3.1	
Industrial management, labor problems	32	1.7	
Salesmanship	49	2.5	
Accounting, cost keeping, estimating	42	2.2	
			50.9
English	334	17.4	
Public speaking	150	7.8	
Business English, technical English	22	1.1	
			26.3
Cultural subjects	133	6.9	
Languages	25	1.3	
			8.2
Practical applications	128		6.7
Psychology	37		1.9
Miscellaneous	115		6.0
	1,923		100.0

17. SUBJECTS WHICH RECENT GRADUATES CONSIDER UNESSENTIAL.

	Number.	Per Cent
Modern languages	170	21.9
Shop work	94	12.1
Descriptive geometry	55	7.1
Military training	21	2.7
Miscellaneous—All other recommendations are so scattering as not to be significant	435	56.2
	775	100.0

Many graduates in answering this question stated that they considered all subjects essential. Others left the answer blank, possibly indicating that they were unable to select any subject as unessential.

18. OPINIONS OF RECENT GRADUATES AS TO IMPROVEMENTS IN ENGINEERING COURSES.

	Number.	Per Cent.	Total Per Cent.
Give business training	134	15.4	
Give more or better engineering economics	6	0.7	
Give more or better general economics	11	1.3	
Teach administrative and executive work	1	0.1	
Teach salesmanship	1	0.1	
			17.6
Lengthen all engineering courses	154		17.7
Give more English, teach public speaking	52		6.0
Give more cultural work, or give it better	138		15.9
Give more practical training	99	11.4	
Use summer vacations for practical work	21	2.4	
Give orientation courses for seniors	11	1.3	
Give students early contact with industry	14	1.6	
Take inspection trips	9	1.0	
			17.7
More or better teachers	17		1.9
More or better teaching of the sciences	43	5.0	
Raise standards of work	12	1.4	
Coordinate the various courses better	3	0.3	
			6.7
Less specialization, more electives	110		12.7
Miscellaneous	33		3.8
	869		100.0

19. STUDY DONE BY RECENT GRADUATES SINCE GRADUATION.

	Number.	Per Cent of those Canvassed.
Positions which require study	2,909	74.0
Positions which do not require study	887	22.5
Number not replying	137	3.5
Study along lines of college course	2,222	56.6
Study not along lines of college course	1,059	26.8
Number not replying	652	16.6
Study supervised by employers	1,105	28.1
Study not supervised by employers	2,255	57.3
Number not replying	573	14.6
Continued interest in and study of cultural subjects	1,693	43.1
Interest in and study of cultural subjects not continued	1,346	34.2
Number not replying	894	22.7

Many of the 3,933 graduates canvassed, indicated more than one method of continuing their studies.

20. STATEMENTS OF OLDER GRADUATES AS TO CONTINUATION OF TECHNICAL EDUCATION SINCE GRADUATION.

(The number of graduates canvassed was 2,336. Many of them indicated more than one method of continuing their technical education.)

	Number.	Per Cent. of Those Canvassed.
Graduate work in a college or university	320	13.7
Extension, correspondence, or similar courses	367	15.7
Courses given, supervised or required by employers	180	7.7
Systematic, self-regulated study	445	19.1
Such unsystematic study as work has demanded	1,464	62.8
Other varieties of study	146	6.3
No study along technical lines	242	10.4

21. REASONS GIVEN BY NON-GRADUATES FOR LEAVING COLLEGE.

	Number.	Per Cent.
Financial difficulty	219	24.3
Scholastic failure	205	22.7
Lack of interest in engineering	89	9.9
Voluntary change of course	90	10.0
War service	106	11.7
Health	72	8.0
Change in status of family	58	6.4
Other reasons	63	7.0

22. CAUSES OF SCHOLASTIC DIFFICULTY OF NON-GRADUATES.

	Number.	Per Cent.	Total Per Cent.
Poor preparation	98	18.2	
Carelessness or neglect on part of student	115	21.4	
Lack of interest or aptitude for engineering	86	16.0	
			55.6
Poor arrangement of course	71	13.2	
Poor presentation of subjects	54	10.0	
			23.2
Self-support	39	7.2	
Time spent in commuting	15	2.8	
			10.0
Social diversions	23	4.3	
Athletics	10	1.9	
Other college activities	5	1.3	
			7.5
Other reasons	20		3.7
			100.0

23. SUBJECTS IN WHICH NON-GRADUATES HAD MOST DIFFICULTY.

	Number.	Per Cent.
Mathematics	204	21.4
Chemistry	155	16.3
Modern languages	120	12.6
Descriptive geometry and drawing	116	12.2
Physics	101	10.6
Mechanics	88	9.3
English	74	7.8
Laboratory courses	39	4.1
Engineering subjects	30	3.2
Shop courses	20	2.1
Others	4	0.4
		100.0

24. OPINIONS OF NON-GRADUATES AS TO PRINCIPAL DEFECTS IN ENGINEERING COURSES.

	Number.	Per Cent.
Too little attention to the problems of the individual student	218	21.4
Failure to correlate study with practice	135	13.3
Examinations given too much weight	109	10.7
Poor teaching	105	10.3
Too much "theory"	92	8.9
Too much history, languages, etc	87	8.6
Too little history, languages, etc	73	7.2
Too much work required	64	6.3
Too many courses given at the same time	49	4.8
Too much shop, drafting, report writing, etc.	46	4.5
Others	41	4.0
		100.0

BULLETIN NUMBER 4
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF
ENGINEERING TEACHING PERSONNEL

Conducted under the Auspices of the
Committee on Teaching Personnel

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ENGINEERING TEACHING PERSONNEL

Purposes.—The purposes of this study were to obtain through statistical means as accurate a conception as possible of certain aspects of the status of engineering teachers in the United States and Canada and upon the basis of that information to prepare conclusions and recommendations looking to the improvement of teaching staffs.

Sources of Information.—Data relating to engineering teachers were obtained through the cooperation of committees of the faculties, through individual teachers, and through the deans or other administrative officers of engineering colleges throughout the two countries. The numbers of institutions and of individuals supplying information are as follows:

Economic status of engineering teachers—2,279 teachers in 75 institutions, 80 per cent of those canvassed supplied information.

Policies pursued by the colleges in connection with recruitment and development of teaching staffs—116 institutions.

Sources from which teachers are drawn and positions which teachers fill when they leave the colleges—71 institutions.

Degrees held by teachers of engineering students—143 institutions and 8,598 teachers.

Teaching loads of engineering teachers—76 institutions and 2,289 teachers.

The institutions included represent all types which offer engineering courses leading to degrees and all parts of the United States and Canada.

Auspices.—The project was carried out under the sponsorship of the Committee on Teaching Personnel:

Charles H. Warren, *Chairman*, Yale University,
W. H. Kenerson, *Secretary*, Brown University,
J. H. Cissel, University of Michigan,
H. E. T. Haultain, University of Toronto,
Charles S. Howe, Case School of Applied Science,

M. S. Ketchum, University of Illinois,
P. F. Walker, University of Kansas.

The committee has presented three reports during the course of its studies. The first two dealt with the accumulated data and presented comments thereon. The other contained the committee's conclusions and recommendations. These reports with such editorial changes as were needed for the purpose, together with the accompanying tables of data have been consolidated and constitute the material which follows. It is divided into three parts. Part I, which presents the committee's discussion of the data, corresponds with the first two reports. Part II presents the committee's conclusions and recommendations. Part III comprises tabular summaries of data.

PART I. DATA RELATING TO ENGINEERING TEACHING PERSONNEL

(The tables of data referred to may be found on pages 305 to 317 inc.)

A. Recruitment and Losses

Sources from Which Engineering Teachers are Obtained.—Data relating to the recruitment of engineering teaching staffs are summarized in Table 1 and Fig. 1. They show that a majority (67.1 per cent) of all positions are filled through promotion from graduating classes and from the teaching ranks, so that the body of our staffs is built up from this source. There is a substantial interchange between schools, ranging from 11.4 per cent in the case of assistants to 37.5 per cent for deans, the average being about one-fifth for all grades. There is also a notable proportion of teachers derived from engineering practice, ranging from about one-fifth for the professorial ranks to about one-third for instructors.

The percentages of instructors and assistants secured from other institutions deserve comment. This number is due in part doubtless to a policy of securing men with varied training and experience, but it is also probably connected with a tendency on the part of the young men themselves to gain experience, or to pursue further study at an institution other than the one from which they graduated. Whatever the cause, it is a healthy situation, pointing as it does to a considerable circulation of young men among the schools.

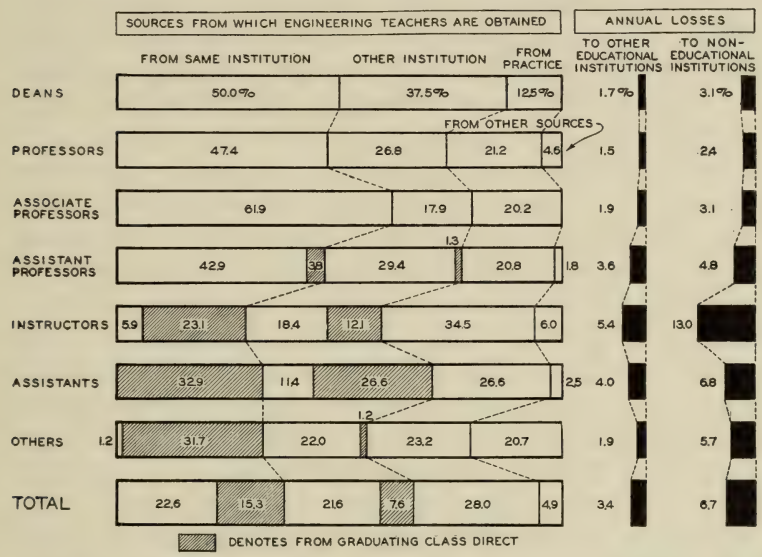

Fig. 1. Sources from which engineering teachers are obtained and annual losses of teachers.

The return of young men from industry is also probably on the whole a satisfactory state of affairs. Many of them probably desire to get a more thorough grasp on theory and plan to do graduate study along with their teaching. They should come back from industrial work with a broadened viewpoint and a clear idea as to what is important in education. We should not overlook the fact, however, that some of these young men come back because they find industrial work not to their taste, or the pace faster than they can maintain. An uncertain proportion of them are probably of doubtful value.

It is significant to note from Table 1 that the number of new men of the rank of instructor and lower who have been added to the staffs in a period of five years exceeds the number of men holding such positions at present. Evidently there is a considerable shifting of teaching personnel in the lower ranks.

Use of Men Regularly Employed in Industry as Auxiliary Teachers.—In connection with this matter it is learned that about one-fourth of the colleges use men from the industries as part-time teachers, and that an equal proportion (though not necessarily the same institutions) supply teachers from the staffs to assist in carrying on educational work for employees. The general opinion is that both of these practices are valuable to a certain extent. It is noted by some institutions that care must be exercised in correlating the work of the man from the industry with that of the regular staff, and in keeping him from going over the head of his class. The outside man may often be inspiring and may present new points of view to the class, but the inference is that instruction of this sort is to be regarded as an auxiliary to, rather than as a substitute for, regular staff instruction.

Losses of Teachers to Practice and Industry.—Commenting on the losses during the five-year period covered by Table 2 (1920 to 1924 inclusive) it appears that the annual turnover for all grades of teachers and for all changes of positions is about ten per cent. The actual annual loss of teachers by the institutions is about seven per cent. In the grades of instructor and assistant the percentage of losses is much larger than in the professorial grades, 11.5 per cent as compared with 3.35 per cent. The total percentages of teachers who change their positions per year to go to other institutions or to leave teaching are as follows: To take another teaching position, 3.37 per cent; to enter practice, 4.46 per cent; to enter business, 1.09 per cent; to enter other activities, 1.13 per cent, a total of 10.1 per cent, as above mentioned. The total loss of teachers above the rank of instructor per year, is about three and one-third per cent of the total number of teachers of those ranks.

B. ECONOMIC STATUS OF ENGINEERING TEACHERS

Salaries and Supplementary Earnings.—The results of this study constitute a successful attempt to picture the financial status of a particular class of individuals. The data are summarized in Tables 3 to 5 inclusive. About 2,850 questionnaire cards were distributed to members of the staffs of seventy-five representative institutions throughout the United States and Canada. Eighty per cent of those canvassed, or a total of 2,279 individuals submitted responses in a form which could be tabulated. It is believed that the figures given in the summary tables are quite reliable and furnish an entirely trustworthy cross-section of the present (1925) financial situation of the teachers of engineering. It may be that a few very large supplementary incomes have not been reported, but since results are reported as medians it is not likely that these few cases would materially affect the results. In this connection it may be noted that a considerable number of incomes in excess of $10,000 per year are included. The tables give figures for academic salaries and ''supplementary'' incomes. The latter include income from all sources except inheritances and gifts.

The figures for maximum and minimum salaries call for little comment. It is possible that the exceptionally low salaries of some individuals of long periods of service may represent shop instructors, or possibly even teachers on part-time, though the cooperating institutions were requested not to circulate questionnaire cards to the latter.

Supplementary Incomes.—Of the 2,279 individuals reporting, 1,785 state that they have supplementary incomes, the percentages for the various ages ranging from 58.5 to 100, with an average for the entire group of 78.5. There is a gradual increase in this percentage, with minor fluctuations. The supplementary incomes show a gradual increase throughout the period, the median figure for those reporting supplementary incomes advancing to $2,000 at its highest point. There is a noticeable but unexplained sudden increase in the supplementary incomes at the twentieth year after graduation. Preceding this year the incomes from supplementary sources range from $600 to $880 per year. At the twentieth year there is a sudden increase to $1,200 per year. From this point on the supplementary incomes in four figures continue. The supplementary incomes rather rarely reach one-third of the median or most frequent salaries.

Earnings of Teachers and Graduates Compared.—The data of this and other studies afford a basis of comparison with the earnings of engineering graduates in practice. Table 6 and Fig. 2 show the ratio of salaries of teachers of engineering to those of graduates. At the start the teachers salary and total earned income exceed the earnings of graduates by a small amount. At the end of one year their total in-

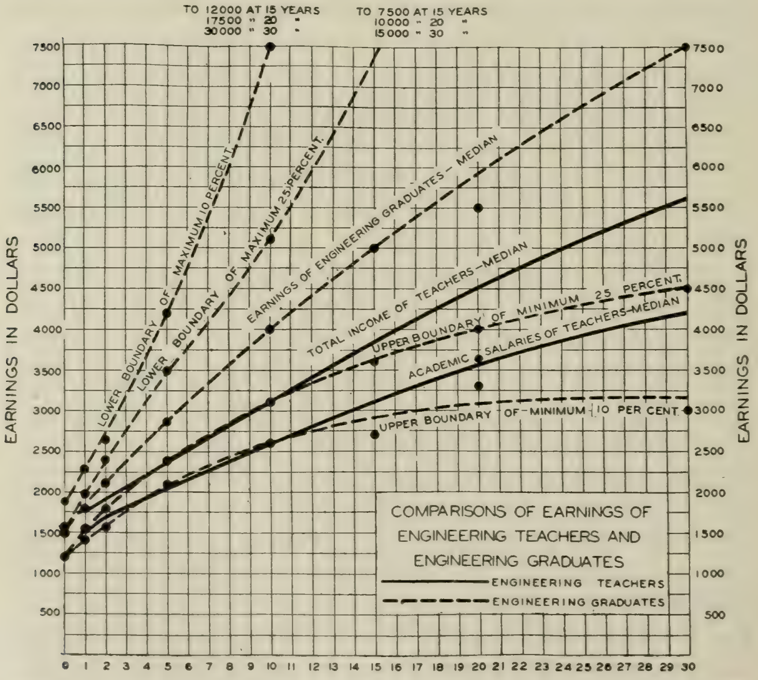

Fig. 2. Comparisons of earnings of engineering teachers and engineering graduates.

Based upon information supplied by 5,023 graduates and 2,279 teachers.

comes are practically equal. After one year the teachers earn steadily less than graduates in practice, until at the thirtieth year after graduation the median total earnings of teachers are but 74 per cent of those of graduates in practice. When academic salaries—either median or most frequent—are made the basis of comparison, the status of the teacher as to earnings is, of course, still less favorable. The young teacher beginning his career must look forward in general to a smaller income than if he went into practice—assuming that his earning capacity in industry is proportionately as great as it is in teaching.

Salaries of Various Teaching Ranks.—Table 5 presents a summary of salaries arranged according to teaching rank. This table includes sixty-nine of the seventy-five institutions of Table 3. The institutions have been carefully chosen and probably give a reliable cross-section of salary levels throughout the United States and Canada. The small median and most frequent salaries of deans and professors are striking. If we compare these salaries with those arranged by years since graduation, using the most frequent salaries as an index, we may conclude that teachers normally reach the rank of assistant professor in about eight years, the rank of associate professor in about fifteen to twenty years, and that of professor in from twenty to twenty-five years.

C. Demands on Teachers' Time

Teaching Loads.—Tables 7 to 10 inclusive and Figs. 3 to 6 inclusive give data regarding the teaching loads of members of engineering faculties. The unit employed is the college "hour" of required presence in classroom or laboratory. No effort has been made to reduce the several types of instructional work to the basis of "credit hours" or similar units, for the reason that there is no accepted standard in use for the purpose. The only universally known and understood unit appears to be the college "hour", a period which is usually of 50 to 55 minutes' duration. It is probably not entirely satisfactory to rate all varieties of instructional work equally, but it would probably be even more unsatisfactory to attempt to use a method of evaluation which had not been accepted in a majority of the institutions.

The general average teaching load carried by teachers of all ranks from which departures for the various grades are surprisingly small, is 17.6 hours per week. Excluding the deans the average load is 18.0 hours per week. It is interesting to note that if the average length of the classroom hour be taken as 55 minutes, the teaching load for engineering teachers (excluding deans) is 990 minutes per week, which is very close to the average for high school teachers carrying a full schedule of 1,000 minutes per week.

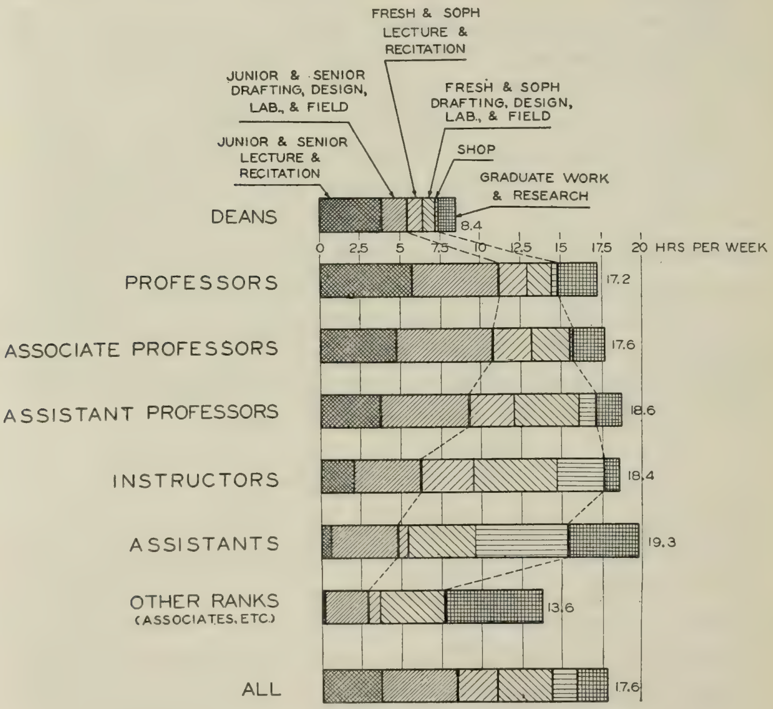

Fig 3. Teaching loads of engineering teachers.

Demands on the Teacher's Time.—Everyone familiar with the situation knows that the number of hours of actual attendance in classroom and laboratory is by no means an accurate indication of the demands upon the teacher's time. To this must be added the time required for preparation for classes and for the planning of problems, projects and experiments; the time required for the maintenance and operation of laboratories, and for correction of problems, reports and examinations. There must also be added the time, often considerable, devoted to conferences and committee assignments. It is very difficult to estimate the time required for these supplementary duties but it is probably quite within the limits of accuracy to state that the teacher who carries on his work conscientiously and assists to a reasonable degree in the committee activities of an engineering college devotes as much time to duties outside of the class room as he does to actual classroom attendance. It must also be remembered that the hours of classroom attendance during the week are not scheduled as a single block but that they come at irregular intervals both in the morning and afternoon, breaking up the day unprofitably as far as really free time is concerned.

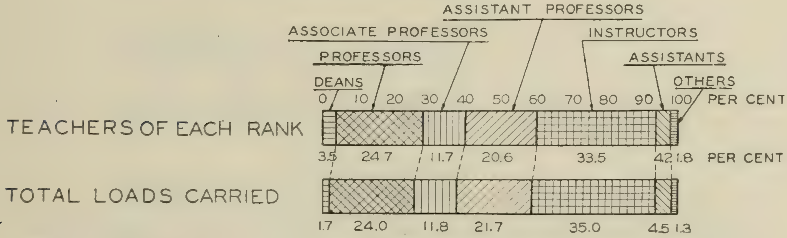

FIG. 4. Relationship between percentage of teachers of each rank and total loads carried.

Proportional Loads of the Several Ranks.—The data bring out one fact very clearly, namely, that each rank carries a teaching load which is in almost exact proportion to the number of teachers in that rank. (See Table 7 and Fig. 4.) The division of teaching staffs as to rank seems on the whole to be quite satisfactory. Deans and professors constitute 28.2

per cent of the total, associate and assistant professors 32.3 per cent and instructors 33.5 per cent. The percentage of full-time men of the rank of "assistant" is small—4.2 per cent, probably not greater than that required to carry the kind of work which can properly be delegated to them. The small proportion of teachers of this rank should be borne in mind in studying the division of teaching loads.

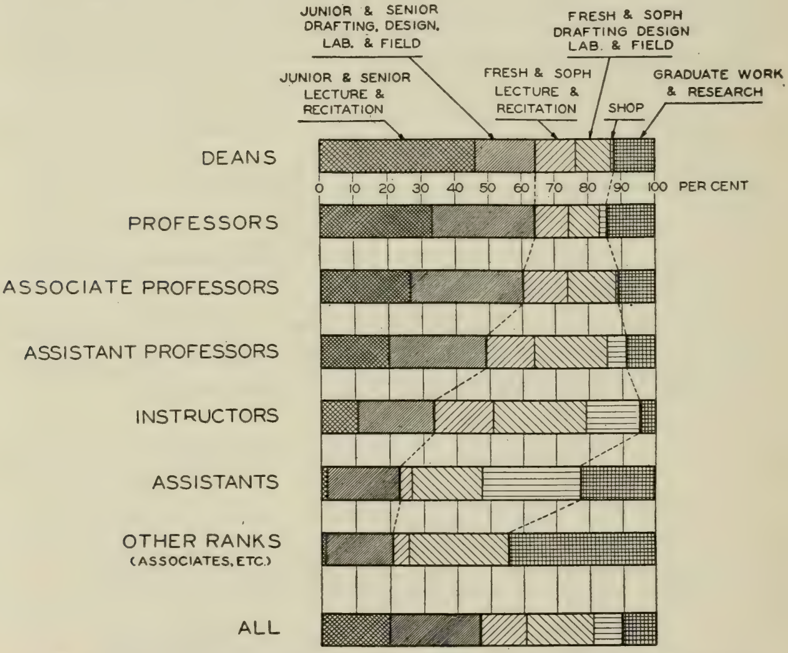

Fig. 5. Percentage distribution of teaching loads of engineering teachers.

Participation in Various Kinds of Instruction.—It is rather striking that while there is, as would be expected, a considerable increase in the load of laboratory, drafting room and shop work as the lower teaching grades are approached, and that a relatively larger proportion of the time of teachers of junior rank is devoted to freshmen and sophomores, there is on the whole a rather general participation of all ranks in all kinds of instructional work. (See Tables 8 and 9, Figs. 3 and 5.) In this connection special attention may be called to the work of teachers of the rank of assistant. It will be noted that there are but ninety-five such teachers on full-time duty in the seventy-six institutions reporting and that while they devote an average of 19.3 hours per week to definitely assigned duties, 15.9 hours of this total are devoted to laboratory, field, shop and research work, but 0.9 hours per week to actual classroom teaching and 2.5 hours per week to drafting and design courses.

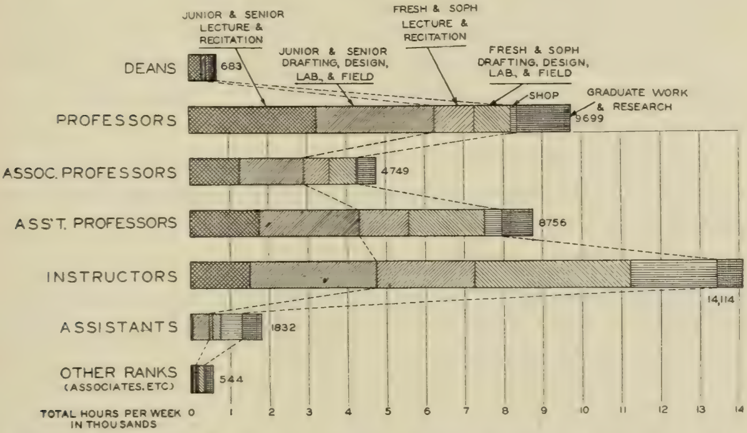

FIG. 6. Division of teaching duties among teachers of various ranks. (Length of bars is proportional to total teaching load of corresponding rank.)

Instruction of Graduate Students.—The tables show that the time devoted to the instruction of graduate students is small throughout the country as a whole, and point to the fact that our engineering education is predominately undergraduate in character, in spite of the fact that about one-half of the institutions offer graduate courses in engineering. It is of course true that many of the larger and stronger institutions give a considerable amount of graduate instruction. This must mean that many engineering schools are giving very little or none at all in order to bring the average down to the small figure shown in the tables.

Time Devoted to Research.—Turning to the figures showing the time devoted by teachers to research work, it should be noted that time devoted to research in connection with outside consulting practice is not included. The results indicate that in our engineering schools as a whole the engineering teacher is not active in research, 1.3 hours per week being the general average for all ranks (Table 8). The *percentage* of the teacher's time devoted to research has less significance, than the *actual* time spent. If this be connected with the fact, also brought out by this investigation, that the amount of outside professional work is not large on the whole, it must be concluded that engineering teachers as a group are mainly occupied with their teaching duties. This is the inevitable outcome of the heavy load of class room duties which the teachers carry.

Again as in the case of graduate study attention should be called to the well-known fact that in the larger and stronger schools a very considerable amount of time is devoted by many members of the teaching staff to research work, so that in order to produce the very low averages for time actually spent in research, there must be many institutions where very little time is spent in this way.

D. Degrees Held by Teachers of Engineering Students

Through the cooperation of the Committee of the Missouri School of Mines and Metallurgy, Table 11 which gives a summary of the degrees held by teachers in the several divisions of engineering curricula is presented. Some interesting contrasts are shown by this table. There appears to be a rather large proportion of teachers of engineering subjects, 14 per cent, who have received no degree. This is in part explained by the fact that many teachers of mechanic arts and probably drawing are recruited directly from practice.

The proportion of teachers of engineering subjects who hold higher engineering degrees compares favorably with the proportion of those teaching chemistry, mathematics, etc., who hold the doctor's degree. Those who hold higher engineering degrees have usually spent a considerable amount of time in engineering practice in fulfilment of the requirements for such degrees. This is as it should be, for each of the two higher degrees represents the completion of an appropriate preparation for a distinct field of teaching.

There is a decidedly larger proportion of those holding bachelor's degrees among engineering teachers than among those in the other divisions. It would be better if there were a larger proportion of men who have extended their study period beyond undergraduate years. This would furnish us with teachers better grounded in theory and practice, provided the graduate study were properly completed or supplemented by engineering practice as a part of the requirement. There is little doubt but that the situation is rapidly improving.

E. Supplementary Professional Practice of Engineering Teachers

Professional Practice during the Academic Year.—The data indicate that teachers are permitted to engage in practice during term time in 96 per cent of the 116 institutions supplying information. Only five institutions among the state universities and state land grant colleges do not permit it. The practice is encouraged in 68.5 per cent, tolerated in 27.0 per cent, and discouraged in only 2.7 per cent of those institutions which permit it. Two institutions (1.8 per cent) did not answer this question. So few institutions impose any restrictions on such work, except that it shall not interfere with the teacher's regular duties, that this appears to be the prevailing practice. The matter is in general left to the good sense of the individual, although in the case of the younger men there is some supervision by those in authority, some fourteen institutions exercising some definite plan of oversight. The type of work which may be done does not seem to have come under close supervision. Fifteen out of the 111 institutions which permit outside work during term time definitely specify it must be such as to advance professional standing.

The fact that there are so few restrictions; that so many encourage outside work by teachers during term time; that there are definite arrangements in many institutions for the purpose of assisting the younger teachers to obtain such work; and that in general the individual members of the staffs are trusted to use their own discretion as to how much and what sort of work they shall do, seems to indicate that the practice is looked upon as a healthy one, and that it has not been abused. The evidence furnished by the data on supplementary incomes of teachers points in the same direction. The incomes from this source are moderate on the average and unless the rate of pay is absurdly small, the total bulk of outside work can hardly be regarded as sufficient to present any really serious problem—this remark applying, of course, to the situation as a whole.

Professional Practice in Industrial and Non-Industrial Centers.—It may be further remarked that the proportion of teachers located in colleges in or near large industrial centers who engage in outside professional work is not materially greater than that of the teachers in more remote institutions. The volume of work done, as judged from amounts earned, however, appears to be considerably greater. The following tabulation gives a rough indication of this situation. The

Comparison of Incomes of Teachers in Industrial and Non-Industrial Centers.

	Years After Graduation.	Number of Individuals.	Number Reporting Supplementary Incomes.	Per Cent Reporting Supplementary Incomes.	Median Total Income.	Median Supplementary Income.
Industrial......	1–10	508	361	71.1	2530	634
Non-Industrial..	1–10	443	281	63.5	2105	408
Industrial......	11–20	392	354	90.5	4270	995
Non-Industrial..	11–20	340	286	84.2	3780	624
Industrial......	21–30	218	194	89.0	5440	1460
Non-Industrial..	21–30	163	138	84.7	4620	1052
Industrial......	31–40	102	95	93.0	6740	2080
Non-Industrial..	31–40	60	50	83.3	4610	1180

figures for income were obtained by averaging medians for ten-year periods.

Use of Laboratories for Outside Work.—This subject is related closely to the previous one. Only three of the institutions which permit outside practice by members of the teaching staff do not permit the use of college laboratories in connection with such work. In 44 per cent of the institutions which do permit the laboratories to be used, materials and certain other costs are paid for by those who use the laboratories. In 40 per cent of the institutions a fee is charged in addition for the use of the laboratory. There are also certain other special regulations. It is to be noted that in only one institution, as far as known, is any definite attempt made in connection with use of laboratories to fix a charge for overhead computed as a certain percentage of labor costs. Why should the institution not be reimbursed for overhead as well as for materials and labor? The former is usually unknown but probably cannot be less than 50 per cent of labor cost. Probably the volume of work has not been great enough to be a serious item and has simply been allowed to go into the general expense account of the institution.

Use of Name of Institution in Connection with Outside Work.—Approximately four-fifths of the colleges look upon the individual doing the work as solely responsible for results, and institutional responsibility is disclaimed or expressly denied. Ten per cent state that the professor may state his identity with the institution, though this probably does not imply any responsibility of the institution for results. Institutions having experiment stations send out official reports confined to data but give no opinion or guarantee as to their value.

F. Opportunities for Development

Sabbatical Leave.—Sixty-five per cent of the institutions have no policies as to sabbatical leaves for teachers of engineering. Thirty-two per cent of the institutions have policies of varying types. The frequency of permitted leaves varies from one-half year in three to one year in eight; the term sabbatical evidently not being confined to its strictly derivative sense. Salary during leave is usually adjusted on the basis of half year with full pay or full year with half pay.

It is rather significant to note that in the past five years only seventy-seven leaves of absence of all kinds have been taken by teachers of engineering in 116 institutions having a total faculty of perhaps three thousand members. The rate is about fifteen individual leaves per year or about 0.5 per cent of the total number of teachers. It would be interesting to know how these figures compare with those for college teachers in other lines. It seems possible that teachers of engineering avail themselves of sabbatical leave to a lesser extent than other teachers. If there were more demand for such leaves it is probable that the practice would be more general, and it is probably a fact that engineering teachers supply the want of leaves of absence through the practical engineering work which they carry on during the college year and in vacations.

Assistance to Younger Teachers in Broadening Their Experience.—Of the 116 institutions reporting, 79 per cent give such assistance while 18 per cent do not. Apparently there is a strong tendency to assist younger teachers to secure vacation employment. One institution, the New Mexico College of Agriculture and Mechanic Arts, not only makes an effort to place its staff in vacation work, but actually provides financial assistance to members of its faculty for pursuit of courses of study, etc. A few others make similar arrangements through grants from endowment funds. This is excellent for the younger men.

Instruction in the Art of Teaching.—Data were gathered on this subject because there is constant criticism from certain sources that the art of teaching is neglected in engineering colleges and that men are hired to teach rather because of their knowledge of the subject than their ability to impart it to others. The returns indicate that 85 per cent of the schools give no systematic instruction in the art; 5 per cent answer in the affirmative for all departments; 5 per cent state that such instruction is given in some departments; and about 5 per cent did not reply to the question. In connection with this matter it is to be noted that in 21 per cent of the institutions it is customary for the older teachers to visit the classrooms of younger teachers, and that in 33 per cent it is customary for the younger teachers to observe the methods of older teachers. About three-fourths of the faculties seem to feel that such instruction is or could be made of substantial value; about one-fifth feel otherwise. There seems to be a rather mild feeling that some sort of instruction might be made of value, but there is much doubt as to whether or not anything worth while can be done, or, if it could be done, who should do it and how.

PART II. CONCLUSIONS AND RECOMMENDATIONS OF THE COMMITTEE

The General Situation.—Beyond the basis of fact now in our possession there is still, as we all recognize, much that is more or less intangible and impossible to set down in cold figures which, nevertheless, must be taken into account in the solution of our educational problems. The basis of fact secured will, however, assist us materially in analyzing and evaluating these less tangible features of our educational environment.

The general situation as regards teaching personnel, in so far as it is disclosed by the data collected, is on the whole an encouraging one. The teachers of engineering subjects are certainly doing their work energetically and conscientiously; they are obviously thoroughly alive to the fact that they have important problems before them and are earnestly and actively seeking their solution. This in itself is an evidence of vitality which indicates that the time is ripe for an advance to a higher level of achievement.

A. Selection of Teachers

Encouraging Aspects.—As pointed out previously, the general situation in this connection is quite satisfactory *insofar* *as can be judged by the statistical evidence presented.* There appears to be a normal and desirable fluidity in the loss and gain of teachers, particularly in the lower grades. The total turnover in all ranks is about ten per cent, which is not unduly large. With an average interchange of teachers of about one-fifth between schools, and with from one-fifth in the professorial ranks to one-third in the ranks of instructor derived from engineering practice, it appears that the engineering schools are providing very satisfactorily for a desirable interchange or circulation of teachers, particularly the younger men, between schools and for a constant addition to the teaching ranks of men who are bringing into teaching the viewpoint of the engineer in practice. This situation seems to afford a guarantee against the danger of too much standardization or the development of too strictly academic an atmosphere.

The losses to practice, industry, and business are relatively small particularly in the higher ranks and there is nothing in the data to support the often heard complaint that industry to a dangerous extent is draining the schools of their best men. It must be remembered, however, that the data cannot show to what extent those whom we do lose are the sort with which we can least afford to part.

Is the Quality Satisfactory?—Are we drawing our younger teachers from among the highest level of those graduating year after year from our engineering schools as measured not alone by their scholastic records but by their character and all round promise? Many of those in administrative positions feel that in general we are not doing so but that industry and practice are getting and holding these men, and that it is in just this way that industry is taking away the best talent from the teaching profession. To avoid a danger of this sort and to obtain the best possible material it will be necessary to render teaching positions so attractive that they will be eagerly competed for. If we can by any means whatsoever render the professorial position one generally recognized as of real prestige, to be gained and held only through severe competition and hard work, our problem is solved. Adequate salaries, larger opportunities to take part in engineering practice and research work, and a more careful scrutiny of candidates on the basis of all-round qualifications, will doubtless be the principal means toward the end desired.

Teachers of Related Non-Engineering Subjects.—Thus far our investigations and comments about teaching personnel have been confined to teachers of engineering subjects or at least to teachers who report to the dean or faculty of engineering. In many universities instruction in mathematics and physics is not under the jurisdiction of the engineering division or school, but under a university department over which the engineering faculty has little or no direct control, and indeed has often very little influence either as to the engaging of teachers or as to the subject matter of the instruction. It is perfectly well known that there is too often a lack of proper coordination between one or both of these subjects and the engineering work. There are often sharp differences of opinion and lack of understanding between the teachers of these subjects and those who teach the technical courses which are themselves so largely compounded of what is essentially physics and mathematics. This is not the place to enlarge upon this matter, but it is a vitally important problem; indeed it seems to be one of the most important problems before the engineering schools today.

B. Teaching Loads

Present Loads Often Excessive.—The teaching load for all ranks is uniformly heavy as compared with that borne in general by academic teachers. The average number of teaching hours (actual contact hours of fifty-five minutes each) is very close to eighteen and there is no great departure from this average for any rank (excluding deans). The general opinion seems to be that eighteen hours of actual teaching is too heavy a load since it certainly entails at least an equal amount of auxiliary work, preparation, marking of papers, etc., and that therefore the total amount of time and effort expended on the teaching duties alone leaves too small a margin of time for developing professional contacts, research, study, recreation, exercise, and in short general self-development. The small amount of outside professional work and the very meager number of hours which on the average are devoted to research work support this contention. Fifteen hours per week seems to be a more desirable general maximum teaching load. Fifteen hours per week for the assistants and young instructors would be considered by some as too light a load. The thought has indeed been expressed that with only fifteen hours of work the assistant or instructor would not have enough work to occupy his time, and would perhaps fall into lazy habits. This result would very likely occur if the young instructor or assistant had no further requirements outside of his required teaching duties. It would seem, however, to be a better practice to require not more than fifteen actual contact hours and then insist that the younger men devote a substantial amount of time to advanced study, research, or practical investigations. It is during this period that scholarly habits of study and research are most easily acquired and if not acquired then, there is grave danger that they never will be. The young instructor is in danger of developing into a mere routine teacher.

Taking all the available facts into consideration it must be concluded that in the engineering schools of the United States and Canada taken as a whole, by far the greater part of the time and energy of the teachers is devoted to the work of undergraduate teaching. The time seems to be ripe for lessening the burden on the individual teacher of the formal undergraduate teaching and for an increase in the time devoted to more advanced instruction, to engineering practice, research, and to whatever tends to enrich and develop the teacher as an engineer and a man.

Balance of Loads Among Teaching Ranks.—It is clear that teachers of all ranks bear their proportional and full share of the teaching load, and that there is a much more satisfactory contact between teachers of all ranks and students of all grades than most of us supposed would be found to be the case. Conditions have probably made it inevitable that a larger proportion of the teaching of the more elementary subjects of the earlier years has fallen on the younger and less experienced though not necessarily less effective teachers. As previously remarked we should guard against any increase in the proportion of the latter class entrusted with the important task of teaching the elementary subjects to the younger students.

Textbook Writing.—In discussing the activities of our teachers the matter of textbook writing has not been touched upon heretofore. The ever-increasing number of textbooks published annually on engineering subjects is sufficient evidence that a great deal of time is used up in this way. One can scarcely avoid thinking of this when contemplating the data on time devoted to research and engineering practice. The value of this work when done by teachers of ripe experience and recognized attainments in their chosen field cannot be questioned. Neither can it be doubted that the younger and less experienced teacher may, through the writing of texts extend and consolidate his knowledge of his subject and improve himself in the exposition of it. We may however fairly question whether the time thus spent might not if spent in productive investigations, research, or in professional work result in a more real and enduring benefit to engineering science and to the teacher himself. It is to be feared that textbook writing is often undertaken by those who find it easier to work over pre-existing material than to produce new material through research. We know many young professors undertake it frankly in the hope of adding to a somewhat meager income and gaining recognition which will lead to a promotion.

C. Compensation and Tenure

Primary Importance of Compensation.—Turning now to the question of what can be done to secure and keep in the teaching ranks men possessed of the characteristics and ability deemed essential to the further progress of engineering education, we come at once to the question of financial remuneration. All will probably agree that this plays a most important part in securing and maintaining satisfactory teaching personnel. Whatever may be said regarding the other compensations which reward the teacher's career, in the last analysis the financial return will be found to be the most important single consideration. The proposition is difficult to state without offense to some of our cherished ideals and without laying ourselves open to the charge of a materialistic bias.

Whatever the reasons may be that lead a young man to enter the teaching profession, one thing is certain; he will not stay in it, if he is a normal young man with ability and courage unless he can be reasonably certain of making a satisfactory living as judged by the commonly accepted standards of the social order in which he finds himself. Moreover every graduating student knows about the small salaries paid to teachers and this knowledge added to certain unfavorable impressions which he may have secured first-hand during his career as a student leads him very often to avoid teaching.

The data show clearly (Fig. 2, page 278) that engineering teachers' salaries even when supplemented by outside earnings are decidedly less than are the incomes of the most nearly comparable class, engineering graduates in practice. Teachers in some specially favored institutions are better off than this, but even here, except for a very few specially favored individuals, the total income does not exceed the median income of the practicing engineer, and does not approach very closely even the lower limit of the income of the maximum twenty-five per cent of engineers in practice. To the young graduate looking forward to a career, the engineering teacher's prospects look at best like a decidedly second rate chance so far as income is concerned.

How the Present Scale Limits Recruitment.—If salaries and total earned incomes of engineering teachers remain on the present basis it will doubtless be true in the future as it has been in the past that the teaching profession will continue to attract able men who are willing to face the smaller financial returns because of the opportunities for study and research, and for the relative freedom and permanency to be found in academic positions. Men in practice who have perhaps laid by a competence and have a taste for scholarly pursuits and an interest in education, and who perhaps have had all the experience in practical affairs they want, will from time to time join the ranks of the teachers. Possibly a permanent and not too strenuous berth with pleasant social accompaniments appeals to them. We shall, however, still continue to get too large a proportion of men who do not represent the highest type of our graduates, and who seem to gravitate toward teaching from negative rather than positive reasons. All administrative officers know how adhesive this type is. We should not lay too great weight on the fact as shown by the data that industry does not appear to be drawing away any considerable proportion of our teachers. Perhaps they take all they believe are of any particular value to them, and some of these may be the very men we need most to keep.

If we are to raise the general standard of our teaching personnel above the present level (and this appears to be the essential and most obvious means of improving engineering education), we must, as remarked above, offer salaries which are at least the equivalent of the financial return which the engineering graduate may reasonably expect to receive in practice. To such a salary the ambitious, energetic, and capable teacher may add a fairly substantial amount by outside practice, but he will even then find himself, so far as income is concerned, in the ranks of the lower part of the upper twenty-five per cent of engineers. We cannot expect a young man of spirit and ability to enter or remain in the teaching ranks if he must occupy an inferior position as judged by the standards of the social order in which he lives in respect to the ordinary relations of life. We must raise our salary scale if we are to have our teaching positions desired and competed for by the kind of men we must have.

Proposed Salary Scale.—In proposing an increased salary scale it is clear that it is impossible to devise one which will be suitable for all schools, and also that to propose such an increase is very easy but to get it is quite a different matter. The scale proposed below should be regarded as a goal toward which we may at least work. It is a scale which will have to be met before long by those schools which aim to provide the highest grade of engineering training such as is being demanded by the public we are striving to serve. Certainly a large portion of the advance will have to be met by larger endowments or grants. Perhaps by means of a more rigorous selection of students worthy of advanced training, the numbers to be taught, and consequently the number of relatively higher paid teachers could be reduced.

The scale herewith proposed is based approximately on the values disclosed by the curve for median incomes and by figures for the incomes of the maximum 25 per cent of graduates in engineering practice. (See Fig. 7.) It is shown in Figure 7 by the step-formed curve. This, as can be seen, is situated rather uniformly above the curve of median incomes for engineers in practice and approaches, or even touches, the lower boundary curve for the maximum 25 per cent of engineers in practice.

Position.	Salary.	Approximate Normal Number of Years After Receiving First Degree.	
Instructor	$ 1,500	1	Yearly Advance
	1,800	2	
	2,100	3	
	2,500	4	
	3,000	5	
	3,500	6	
Assistant Professor	4,000	8	Appointments and Advancements at two year intervals
	4,500	10	
	5,000	12	
	5,500	14	
Associate Professor	6,000	17	Appointments and Advancements at three year intervals
	6.500	20	
Professor	7.500	21 et seq.	
Increase to maximum of	12,000		

This salary scale starts at $1,500, for the reason that this figure represents about as much as an inexperienced man just out of college ought to expect. This is in fact about the salary that a graduate would receive if he took a position with an engineering concern or with some industrial company. An exceptionally good man or one having a year of practical experience might be started at $1,800. Perhaps the latter figure may also be taken to be a fair beginning salary for an engineering teacher who has taken postgraduate work. Exceptional cases will naturally occur and will have to be treated as circumstances dictate. On the whole it is felt that the engineering colleges should adhere rather closely to the general rate of remuneration for beginners that obtains in outside engineering practice. The data indicate that a somewhat

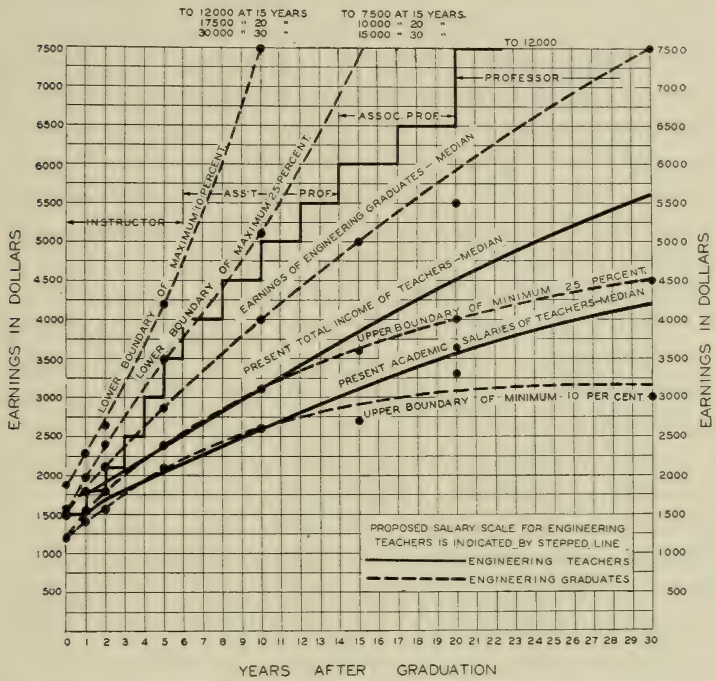

FIG. 7. Proposed salary scale for engineering teachers.

higher rate of pay for first appointments prevails in a considerable number of institutions at the present time. Two thousand dollars is not uncommon and apparently even more is sometimes paid. These higher initial salaries are doubtless offered in an attempt to secure a better grade of man and are intended to overcome the competition with industries and those institutions where a higher scale of salaries prevails in the upper ranks. The wisdom of over-bidding the general market is very doubtful. A far sounder policy is to adhere rather closely to the initial salaries paid in outside engineering practice. It is not the initial salary that will secure and hold the type of man we want but rather the prestige and general desirability of the highest positions.

Proposed Normal Schedule of Promotion.—Provision is made for a steady and rapid yearly increase up to $3,500. The data indicate that promotion to the first professorial grade comes, if at all, usually within the first eight years. This seems a reasonable apprenticeship, but if for any reason it appeared desirable to shorten or lengthen this period the salary appropriate to the position should be paid. During the assistant professorial period a substantial salary beginning at $4,000 with $500 increases at two year intervals is proposed. It is during this time of life that the teacher generally feels most keenly the pinch of insufficient means. During this time he should be in a position to make social and professional contacts and have time for research work and for some recreation and exercise. To cramp him here is to prejudice his future prospects of growth. The same applies to the associate grade.

It is assumed that men will not be passed into the associate grade unless they have pretty fully demonstrated their ability and are in line for a professorship. On the other hand it might be a grade appropriate for the occasional man whose value as a teacher, or as a teacher and officer, is well recognized but whose all-round attainments are not such as to single him out for the highest rank. If the position is well paid it will be rated as a dignified and worthy office, a step below the highest rank attainable.

For the full professor a minimum salary approximating the present day maximum of our engineering colleges is proposed. Provision is made for advance on the basis of length of service, or achievements, or both. The maximum of $12,000 should be paid only for unusual achievement, and in recognition of the highest merit. We believe that this is as it should be, for in the professorial grade we ought to be dealing only with the man whose talents would win him a handsome reward in any calling. As remarked above it is the attractive character of the higher positions which in the long run will attract and hold men of the highest character and ability.

Tenure.—The question of permanent tenure has been made the subject of study by the American Association of University Professors; this investigation has not heretofore touched upon it. Permanent tenure is generally looked upon at present as an accepted prerogative of the teacher which profane hands must not touch. If however, any such salaries as herein proposed for the full professorial rank were actually put in operation there would be some of those concerned with the administrative side of education who would at once raise the question as to whether the permanency feature of the full professor's position might not be omitted with substantial benefit to education. If the remuneration is adequate why should a professor be guaranteed a permanent position irrespective of the manner in which he continues to do his work any more than a man in any other position of responsibility?

D. Personal and Professional Development

The Importance of Practice.—The nature of the teacher's work tends in some measure toward monotony. The constant reiteration of facts and principles to immature students, less wise and experienced than the teacher himself, tends toward pedantry and often develops a false sense of infallibility. Some of those qualities of character and personality which are called into play and developed by work in the practical world outside, lie dormant or tend to atrophy under the conditions that surround the teacher. He is not unlikely to withdraw himself from the interests and contacts of a world which he is nevertheless preparing his students to enter. To offset these dangers, it is important that the engineering teacher should have every opportunity to secure a sufficient contact with the problems which his brother engineer in practice is working on and with the conditions under which these problems must be solved. He should know from adequate and actual experience what things are done in practice, and how they are done. This will serve to furnish him with a proper perspective not only for his teaching but for the exacting work of research and investigation of a theoretical nature which, we take it, is one of the special functions of the engineering teacher. These contacts also increase his self-respect, the respect in which he is held by his students, and give him a standing in the community which cannot fail to react favorably on his career.

This investigation has shown that engineering schools fully recognize the importance of this. In over two-thirds of them some form of professional practice is encouraged during the academic year and in the remaining third, with a very few exceptions, such practice is at least permitted.

The importance of professional practice during the vacation is also generally recognized and encouraged. Indeed a teacher of engineering subjects who does not utilize some part of his vacation for active professional work of one sort or another is likely to be looked upon with disapproval.

There appears to be no reason to suppose that this professional work, whatever its nature, is regarded as in any way interfering with teaching duties. Where such interference appears it can be effectually controlled. There are of course great variations in the amount done by different individuals, even in a single institution, but judging by the amounts earned it does not appear that on the average there is as much of this work done as is commonly supposed.

Positive Encouragement Justified.—It seems to be clear that it would be advantageous if all engineering schools not only encouraged their teachers to do a reasonable amount of outside professional work, but actually insisted on it and made a systematic and organized effort to promote it. Such action with reference to the younger teachers before they have become permanently settled in teaching positions would be most beneficial. Particular emphasis may be laid on the importance of such opportunities during vacations, for then is the most favorable time for a satisfactory and mutually advantageous cooperation with industry. The benefit is not confined to the teacher; the industry will profit by the services of men thoroughly masters of theory; the schools will render a correspondingly greater service to the community; the students will discover very quickly that their teachers are not merely teachers but doers, and will respect them accordingly.

It is perhaps needless to qualify these statements by remarking that the character of the work should be such as to provide an experience which will react favorably on the academic work. Mere ''pot-boiling'' jobs should be avoided.

Sabbatical Leave.—Only a third of the engineering colleges have any definite provisions for sabbatical or other regular leave, and only an insignificant number of engineering teachers avail themselves of the privilege where it exists. The question is obviously not a very live one. Leaves of absence might, however, well be made a more general practice. Such leaves should be granted so that members of the staff could devote themselves to study, research, or professional work calculated to advance their standing and afford them a desirable change of environment. The time of taking the leave and its duration should always be determined on the merits of the individual case.

Exchange of Professors.—Although not touched upon in the questionnaire, the question of exchange of teachers for stated periods between our engineering schools should be considered. The practice is rarely indulged in by the engineering schools although not uncommon between colleges of liberal arts. Several quite obvious advantages both to institutions and the individuals participating would doubtless result from such exchange, and it is hereby recommended as a subject to be given careful consideration.

Training and Developing of Teachers.—It is felt by many that a good deal could and should be done in the matter of training younger teachers. There is evidently a good deal of very honest and well founded scepticism among the teaching fraternity as to whether one can be taught how to teach. A great many express such opinions as "teachers are born not made;" "you are a good teacher or you are not;" "one has to learn by experience, by trial and error;" "schools must find out who is successful and who is not, and act accordingly," and the like.

There is doubtless much truth in all this, but even those who are *born* teachers can be *made better* teachers by direct instruction in the art of teaching. All those who have to act on the administrative side of education are painfully aware of the injustice that is inflicted on the student, particularly in elementary but basal courses where the instruction is even in part in the hands of inadequately trained teachers. This is probably in part unavoidable but there is certainly too little close supervision of young teachers and too little direct training.

In the first place something can be done by way of developing the value of the departmental meetings which are held generally throughout our engineering schools. If these conferences are held frequently enough and include discussions of the content of the courses offered by the department, the methods of presentation and marking, and the best possible correlation with related subjects both within and without the department, they are extremely valuable to the younger teacher. Too much standardization however should be avoided in order to preserve individual initiative and inventiveness.

It is believed that the younger teachers might with advantage visit the classroom exercises of the older and more experienced teachers more generally than they do at present. Whether the more experienced teachers who have charge of the various courses could with equal advantage follow the practice of visiting classrooms of young teachers is not perhaps so clear. It is difficult for most young teachers, unless they are dangerously self-confident, not to say conceited, to carry through a lecture or recitation with any justice to themselves if a more experienced teacher suddenly appears in their classroom. The reaction on the students may also be unfortunate. However, it seems certain that if the element of embarrassment could be removed, the more experienced teachers could secure through such classroom visits first-hand knowledge of the inadequacies of the younger teachers and would as a result be in a position to help them very materially by constructive criticism and suggestions. If it were a generally accepted practice in all schools for those in charge to visit at regular intervals the classrooms of the younger men, and if this were done in a kindly and tactful manner it is probable that there would be no serious embarrassment to either teacher or students and that very substantial benefits would result.

Where a competent teacher of psychology and of the general principles of teaching is available every young teacher and many older ones would profit materially by attending his classes. Some even go so far as to believe that a little elementary instruction in the use of the voice and in classroom manners would be a good thing.

A Qualifying Period of Practice.—The importance of professional work of one kind or another in the development of the engineering teacher and the wholesome practice of drawing to our staffs a considerable number of engineers from practice have been noted. Many in the engineering profession believe that no man should be appointed to a permanent position on an engineering faculty unless he has had several years of actual engineering practice quite aside from any professional experience incidental to teaching work. They insist that after a few years of teaching experience following the completion of his formal education the young instructor or assistant professor should devote himself to engineering practice for several years as a vital part of his training leading toward a later career as a teacher. There are obviously strong arguments in favor of such a practice. In general adoption is not practicable perhaps at present and it may never be wise to insist on it for all teachers, but it is a matter that should be given very careful consideration, for few will be disposed to deny that the engineering teacher who has had the experience of actual practice possesses a background and point of view which can hardly fail to make him a more successful instructor of young men who are being prepared for engineering work.

E. Conclusion

There will be little disagreement with the statement that the real problem before us is that of securing the right type of teachers for our engineering faculties—that this constitutes a major problem in engineering education. On it hangs the satisfactory solution of our most serious educational difficulties. It has been well said that engineering education will never be better than its teachers. The data presented are, we believe, furnishing us with a reliable basis of fact which will help materially in deciding the future course of action in this vital matter.

PART III. TABULAR SUMMARY OF DATA

1. Sources from which Teachers were Obtained.

(Figures Give the Numbers Obtained from Each Source during the Calendar Years 1920 to 1924 Inclusive.)

Rank.		By Promotion in Staff of Same Institution.	From Staff of Another Institution.	From Graduating Class of Same Institution.	From Graduating Class of Another Institution.	Total from Teaching Staffs or Graduating Classes Cols. 2 to 5 Incl.	From Engineering Practice.	From Other Sources.	Totals Cols. 6 to 8 Inc.	Present Numbers of Each Rank in Institutions Represented.
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dean:	No.	16	12			28	4		32	70
	%	*50.0*	*37.5*			*87.5*	*12.5*			
Professor:	No.	83	47			130	37	8	175	487
	%	*47.4*	*26.8*			*74.3*	*21.2*	*4.6*		
Associate Professor:	No.	104	30			134	34		168	207
	%	*61.9*	*17.9*			*79.8*	*20.2*			
Assistant Professor:	No.	163	112	14	5	294	79	7	380	376
	%	*42.9*	*29.4*	*3.8*	*1.3*	*77.4*	*20.8*	*1.8*		
Instructor:	No.	57	178	223	117	575	334	59	968	630
	%	*5.9*	*18.4*	*23.1*	*12.1*	*59.4*	*34.5*	*6.0*		
Assistant:	No.		9	26	21	56	21	2	79	94
	%		*11.4*	*32.9*	*26.6*	*70.9*	*26.6*	*2.5*		
Others:	No.	1	18	26	1	46	19	17	82	84
	%	*1.2*	*22.0*	*31.7*	*1.2*	*56.1*	*23.2*	*20.7*		
Total	No.	424	406	289	144	1,263	528	93	1,884	1,948
	%	*22.6*	*21.6*	*15.3*	*7.6*	*67.1*	*28.0*	*4.9*		

2. LOSS OF TEACHERS DURING THE FIVE-YEAR PERIOD 1920 TO 1924 INCLUSIVE.

Rank.	Left to Take Another Teaching Position.	Per Cent.	Left to Enter Field of Engineering Practice.	Left to Enter Business.	Left to Enter Other Fields.	Total Losses for 5 Year Period Cols. 4, 5 and 6.	Percentage Loss of Each Rank Per Year.	Present Total Numbers in Institutions Represented.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dean	6	1.7	4	3	4	11	3.1	70
Professor	36	1.5	36	7	15	58	2.4	487
Associate Professor	21	2.0	25	5	2	32	3.1	207
Assistant Professor	67	3.6	57	22	11	90	4.8	376
Instructor	171	5.4	274	65	70	409	13.0	630
Assistant	19	4.0	23	1	8	32	6.8	94
Others	8	1.9	16	3	5	24	5.7	84
TOTALS	328	3.4	435	106	115	656	6.7	1,948
Percentage per year of present total number of teachers	3.37		4.46	1.09	1.18	6.73		

(Teachers deceased or retired are not included in the tables. Average percentage yearly loss, professorial ranks—3.35 per cent. Average percentage yearly loss, lower ranks—11.5 per cent. Total percentage turnover per year—10.1 per cent.)

3. Academic Salaries and Supplementary Incomes of Teachers of Engineering in the United States and Canada.

2,279 Individuals Reporting.
Years Since First Degree was Obtained, as of June, 1925.
75 Institutions Represented, as Follows:

23 in New England and Middle Atlantic States,
10 in Rocky Mountain States,
4 in Pacific Coast States,
5 in Canada,
13 in Southern States,
20 in Middle Western States.

(Supplementary income includes all income not derived from academic salary or from inheritances or gifts.)

Years Since First Degree was Obtained.	Total Number Reporting.	Individuals Reporting Supplementary Incomes.		Annual Academic Salaries.		Median Annual Supplementary Incomes of those Reporting Same.	Annual Total Incomes.	
		Number.	Per Cent.	Median.	Most Frequent.		Median of those Reporting Supplementary Incomes.	Median, All Individuals Included.
1	76	53	69.8	$1,500	$1,800	$ 300	$1,900	$1,750
2	115	71	61.7	1,700	1,800	400	2,000	1,900
3	101	59	58.5	1,800	2,000	325	2,100	2,000
4	110	65	59.0	1,900	1,800	393	2,400	2,200
5	108	69	63.9	2,000	*1,800–2,000	483	2,700	2,400
6	83	59	71.1	2,225	2,000	550	2,900	2,675
7	75	55	73.4	2,200	2,000	500	2,850	2,700
8	93	64	68.9	2,400	2,400	600	3,100	2,850
9	71	53	74.6	2,400	*2,400–3,000	600	3,075	3,000
10	118	91	77.1	2,550	3,000	625	3,300	3,075
11	83	66	79.5	2,800	2,700	679	3,550	3,300
12	75	60	80.0	2,850	2,500	700	3,750	3,550
13	61	51	83.6	3,000	3,000	600	3,550	3,500
14	90	80	88.9	3,000	3,000	600	3,525	3,450
15	81	69	85.2	3,000	3,000	795	3,900	3,800
16	63	48	76.2	3,000	2,800	800	4,150	4,000
17	82	73	89.0	3,200	3,000	600	4,000	4,000
18	70	63	90.0	3,300	3,000	880	4,200	4,050
19	61	53	87.0	3,600	4,000	720	4,850	4,550
20	86	77	89.6	3,500	4,000	1,200	4,875	4,600
21	43	37	86.1	3,625	*3,500–5,000	1,000	4,900	4,500
22	52	42	80.8	3,500	*3,000–4,000	1,210	4,800	4,700
23	35	30	85.7	4,000	4,000	1,350	5,400	5,250
24	52	45	86.5	3,700	3,500	1,000	4,750	4,500
25	42	38	90.5	3,600	4,000	1,000	4,600	4,500

TABLE 3.—*Continued.*

Years Since First Degree was Obtained.	Total Number Reporting.	Individuals Reporting Supplementary Incomes.		Annual Academic Salaries.		Median Annual Supplementary Incomes of those Reporting Same.	Annual Total Incomes.	
		Number.	Per Cent.	Median.	Most Frequent.		Median of those Reporting Supplementary Incomes.	Median, All Individuals Included.
26	25	24	96.0	4,300	*4,500–5,000	1,550	5,300	5,250
27	26	26	100.0	4,225	*3,500–4,500	1,700	5,750	5,750
28	25	22	88.0	4,500	5,000	1,475	5,700	5,550
29	34	31	91.3	4,000	4,500	1,375	5,850	5,500
30	47	37	78.7	4,400	5,000	1,700	6,700	5,600
†31	25	22	88.0	4,225	*4,500–5,000–6,000	1,550	6,000	5,825
†32	21	21	100.0	4,200	5,000	1,800	6,550	6,000
†33	15	12	80.0	4,225	4,000	1,350	6,000	5,825
†34	22	20	91.0	4,275	4,500	1,650	6,000	5,725
†35	21	18	85.7	4,400	4,500	1,377	6,000	5,600
†36	11	10	91.0	4,500	4,500	1,200	5,650	5,150
†37	12	10	83.3	4,500	4,500	1,000	5,500	5,400
†38	11	10	91.0	4,500	4,500	1,333	6,000	5,950
†39	10	9	90.0	4,650	*4,500–6,000	1,402	6,600	6,000
†40	14	13	93.0	4,800	6,000	1,775	6,800	6,600
†41	7	6	85.7	5,000	6,000	2,100	7,500	7,250
†42	6	6	100.0	4,800	6,000	2,000	6,800	6,600
†43	5	4	80.0	5,000	6,000	1,800	7,500	6,400
†44	3	2	66.7	4,800	6,000	3,000	6,000	6,000
†45	1	1	100.0	4,500	*3,000–4,000 5,000–6,000	2,100	6,250	6,500
46	2	2	Medians have not been computed because of small number of individuals.					
47	4	3						
48	2	2						
49	1	1						
50	0	0						
51	1	1						
52	0	0						
53	1	1						
54	0	0						
55	1	0						

* Equal numbers of salaries of amounts shown reported.

† Medians computed for five-year period.

4. Maximum and Minimum Academic Salaries Reported.
(2,279 Individuals in 75 Institutions Included.)

Years Since First Degree was Obtained.	Maximum Academic Salary Reported.	Minimum Academic Salary Reported.	Years Since First Degree was Obtained.	Maximum Academic Salary Reported.	Minimum Academic Salary Reported.	Years Since First Degree was Obtained.	Maximum Academic Salary Reported.	Minimum Academic Salary Reported.
1	$2,400	$ 500	16	$6,000	$1,800	31	$8,000	$2,200
2	3,050	750	17	6,000	1,800	32	7,000	3,000
3	3,000	600	18	7,000	1,600	33	6,000	2,400
4	4,000	800	19	6,000	1,650	34	7,200	2,600
5	3,800	500	20	7,000	2,000	35	7,000	2,000
6	3,600	1,200	21	6,000	2,000	36	7,000	2,100
7	4,000	800	22	7,000	2,000	37	6,000	2,400
8	4,900	1,500	23	6,500	2,600	38	6,300	3,500
9	3,800	800	24	6,300	2,000	39	8,000	2,250
10	5,000	1,400	25	8,000	1,800	40	7,500	2,400
11	5,000	1,500	26	6,000	2,800	41	7,200	4,200
12	5,000	1,800	27	7,500	1,800	42	6,000	1,800
13	4,500	800	28	7,000	2,600	43	5,000	3,500
14	6,000	1,500	29	7,500	2,400	44	6,000	3,000
15	6,000	1,600	30	10,000	1,500	45	4,000	4,000

5. Summary of Salary Scales in 69 Representative Institutions.

Rank.	No. of Each Rank	Maximum.	Minimum.	Median.	Most Frequent.
Dean	54	$10,000	$2,500	$5,000	$5,000
Professor	700	7,500	2,500	4,000	4,000
Associate Professor	350	6,000	2,000	3,300	3,500
Assistant Professor	539	5,000	1,500	2,700	2,500
Instructor	831	3,000	900	2,000	2,000
Assistant	137	2,400	250	800	800
"Associate"	20	4,500	2,200	2,500	2,500
TOTAL	2,631				

6. COMPARISON OF SALARIES AND TOTAL EARNINGS OF ENGINEERING TEACHERS WITH EARNINGS OF ENGINEERING GRADUATES IN PRACTICE.

(Values taken from smooth curves.)

Years After Graduation.	Median Annual Academic Salaries of Teachers.	Median Total Annual Earned Income of Teachers.	Median Total Annual Earnings of Graduates.	Ratio: Salary of Teachers to Earnings of Graduates.	Ratio: Total Income of Teachers to Earnings of Graduates.
0*	$1,500	$1,500	$1,475	1.02	1.02
1	1,500	1,750	1,800	.83	.97
2	1,700	1,900	2,100	.81	.905
5	2,000	2,350	2,860	.70	.82
10	2,550	3,100	4,000	.64	.775
15	3,100	3,825	5,000	.62	.765
20	3,600	4,500	5,900	.61	.76
30	4,225	5,550	7,500	.56	.74

* First appointment.

7. DISTRIBUTION OF TEACHERS OF VARIOUS RANKS AND TOTAL NUMBER OF HOURS PER WEEK OF TEACHING DUTIES CARRIED.

(Only teachers reporting to the Dean of Engineering are included.)

	No. of Teachers of Each Rank.	Per Cent. of Total No. of Teachers.	Per Cent. of Total Load Carried.	Load—No. of Hours* per Individual per Week.
Deans or Directors	81	3.5	1.7	8.4
Professors	565	24.7	24.0	17.2
Associate Professors	269	11.7	11.8	17.6
Assistant Professors	472	20.6	21.7	18.6
Instructors	767	33.5	35.0	18.4
Assistants	95	4.2	4.5	19.3
Other ranks (Associates, etc.)	40	1.8	1.3	13.6
TOTALS	2,289	100.0	100.0	Av. 17.6

* An "hour" is a college period of from 50 to 55 minutes.

8. DISTRIBUTION OF TEACHING DUTIES IN HOURS* PER WEEK FOR TEACHERS OF EACH RANK.

(Only teachers reporting to the Dean of Engineering are included.)

Rank.		Lectures and Recitations.		Drafting and Design.		Laboratory and Field.		Shop.	Graduate Courses.	Research Work.	Total.
		Junior and Senior.	Fresh. and Soph.	Junior and Senior.	Fresh. and Soph.	Junior and Senior.	Fresh. and Soph.				
Deans or Directors	Hours	3.89	1.01	0.73	0.42	0.81	0.47	0.05	0.44	0.61	8.43
	Per Cent.	*46.1*	*12.0*	*8.6*	*5.0*	*9.6*	*5.6*	*0.6*	*5.3*	*7.2*	*100.0*
Professors	Hours	5.7	1.8	2.5	0.7	2.8	0.9	0.3	1.0	1.5	17.2
	Per Cent.	*33.1*	*10.3*	*14.6*	*4.2*	*16.2*	*5.1*	*1.8*	*5.8*	*8.9*	*100.0*
Associate Professors	Hours	4.7	2.3	2.0	1.2	4.0	1.3	0.06	0.8	1.2	17.6
	Per Cent.	*26.9*	*13.3*	*11.3*	*7.0*	*22.6*	*7.5*	*0.3*	*4.5*	*6.6*	*100.0*
Assistant Professors	Hours	3.7	2.7	1.3	2.1	4.2	2.0	1.0	0.4	1.2	18.6
	Per Cent.	*20.2*	*14.4*	*6.9*	*11.3*	*22.3*	*10.7*	*5.6*	*2.3*	*6.3*	*100.0*
Instructors	Hours	2.0	3.2	0.8	2.5	3.4	2.7	2.9	0.1	0.8	18.4
	Per Cent.	*10.8*	*17.5*	*4.4*	*13.6*	*18.5*	*14.4*	*15.9*	*0.7*	*4.2*	*100.0*
Assistants	Hours	0.3	0.6	0.6	1.9	3.6	2.2	5.7		4.4	19.3
	Per Cent.	*1.6*	*3.5*	*3.0*	*9.7*	*18.6*	*11.5*	*29.5*		*22.6*	*100.0*
Other ranks	Hours	0.1	0.7		0.2	2.7	3.9		0.3	5.7	13.6
	Per Cent.	*1.1*	*4.8*		*1.5*	*20.0*	*28.3*		*2.2*	*42.1*	*100.0*
Average—All ranks combined	Hours	3.6	2.4	1.4	1.7	3.4	1.8	1.5	0.5	1.3	17.6
	Per Cent.	*20.2*	*13.7*	*8.1*	*9.6*	*19.1*	*10.4*	*8.6*	*2.8*	*7.5*	*100.0*
Total—Deans not included	Hours	3.5	2.5	1.5	1.7	3.5	1.9	1.6	0.5	1.3	18.0
	Per Cent.	*19.4*	*13.9*	*8.3*	*9.5*	*19.4*	*10.6*	*8.9*	*2.8*	*7.2*	*100.0*

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* An "hour" is a college period of from 50 to 55 minutes.

9. DIVISION OF VARIOUS TYPES OF INSTRUCTION OF UPPER AND LOWER CLASSES AMONG TEACHERS OF VARIOUS RANKS.

(Instruction given by teachers who do not report to the engineering dean is not included in the table.)

Rank.	Teachers of Each Rank, %.	Lectures and Recitations.		Drafting and Design.		Laboratory and Field.		Shop, %.	Graduate Courses, %.	Research Work, %.	Total. %.
		Jun. and Senior, %.	Fresh. and Soph., %.	Jun. and Senior, %.	Fresh. and Soph., %.	Jun. and Senior, %.	Fresh. and Soph., %.				
Deans or Directors	3.5	3.9	1.5	1.8	0.9	0.9	0.9	0.1	3.2	1.6	1.7
Professors	24.7	39.4	18.1	43.0	10.6	20.4	11.7	5.1	49.7	28.6	24.0
Associate Professors	11.7	15.7	11.4	16.4	8.6	13.8	8.5	0.4	19.3	10.4	11.8
Assistant Professors	20.6	21.7	22.8	18.4	25.6	25.3	22.3	14.2	17.5	18.3	21.7
Total professorial rank	60.5	80.7	53.8	79.6	45.7	60.4	43.4	19.8	89.7	58.9	59.2
Instructors	33.5	18.8	44.6	18.7	49.5	33.8	48.0	64.7	9.2	19.7	35.0
Assistants	4.2	0.4	1.1	1.7	4.6	4.4	5.0	15.5		13.8	4.5
Other ranks	1.8	0.1	0.5		0.2	1.4	3.6		1.1	7.6	1.3
Total: Instrs., Assts. and others	39.5	19.3	46.2	20.4	54.3	39.6	56.6	80.2	10.3	41.1	40.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

10. CONDENSED SUMMARY OF DATA SHOWN IN TABLES 7, 8, AND 9.

Rank.	Teachers of Each Rank.		Lectures and Recitations.				Drafting and Design.				Laboratory and Field.			
			Jun. and Senior Hours.		Fresh. and Soph. Hours.		Jun. and Senior Hours.		Fresh. and Soph. Hours.		Jun. and Senior Hours.		Fresh. and Soph. Hours.	
	No.	%.	No.	%.	No.	%.	No.	%.	No.	%.	No.	%.	No.	%.
Deans or Directors	81	3.5	315	3.9	82	1.5	59	1.8	34	0.9	66	0.9	38	0.9
%			46.1		12.0		8.6		5.0		9.6		5.6	
Professors	565	24.7	3214	39.4	1001	18.1	1410	43.0	410	10.6	1574	20.4	495	11.7
%			33.1		10.3		14.6		4.2		16.2		5.1	
Associate Professors	269	11.7	1278	15.7	631	11.4	537	16.4	331	8.6	1070	13.8	357	8.5
%			26.9		13.3		11.3		7.0		22.6		7.5	
Assistant Professors	472	20.6	1768	21.7	1263	22.8	603	18.4	988	25.6	1955	25.3	940	22.3
%			20.2		14.4		6.9		11.3		22.3		10.7	
Instructors	767	33.5	1532	18.8	2474	44.6	615	18.7	1918	49.5	2612	33.8	2026	48.0
%			10.8		17.5		4.4		13.6		18.5		14.4	
Assistants	95	4.2	30	0.4	63	1.1	55	1.7	178	4.6	341	4.4	210	5.0
%			1.6		3.5		3.0		9.7		18.6		11.5	
Other ranks	40	1.8	6	0.1	26	0.5			8	0.2	109	1.4	154	3.6
%			1.1		4.8				1.5		20.0		28.3	
TOTALS	2289	100.0	8143	100.0	5540	100.0	3279	100.0	3867	100.0	7727	100.0	4220	100.0
%			20.2		13.7		8.1		9.6		19.1		10.4	

TABLE 10. *Continued.*

Rank.	Teachers of Each Rank.		Shop Hours.		Graduate Course Hours.		Research Work Hours.		Total Hours.		Hours per Individual per Week.
	No.	%.	No.	%.	No.	%.	No.	%.	No.	%.	
Deans or Directors	81	3.5	4	0.1	36	3.2	49	1.6	683	1.7	8.43
%			0.6		5.3		7.2		100.0		
Professors	565	24.7	178	5.1	557	49.7	860	28.6	9699	24.0	17.2
%			1.8		5.8		8.9		100.0		
Associate Professors	269	11.7	15	0.4	216	19.3	314	10.4	4749	11.8	17.6
%			0.3		4.5		6.6		100.0		
Assistant Professors	472	20.6	492	14.2	196	17.5	551	18.3	8756	21.7	18.6
%			5.6		2.3		6.3		100.0		
Instructors	767	33.5	2244	64.7	103	9.2	590	19.7	14114	35.0	18.4
%			15.9		0.7		4.2		100.0		
Assistants	95	4.2	540	15.5			415	13.8	1832	4.5	19.3
%			29.5				22.6		100.0		
Other ranks	40	1.8			12	1.1	229	7.6	544	1.3	13.6
%					2.2		42.1		100.0		
TOTALS	2289	100.0	3473	100.0	1120	100.0	3008	100.0	40377	100.0	17.6
%			8.6		2.8		7.5		100.0		

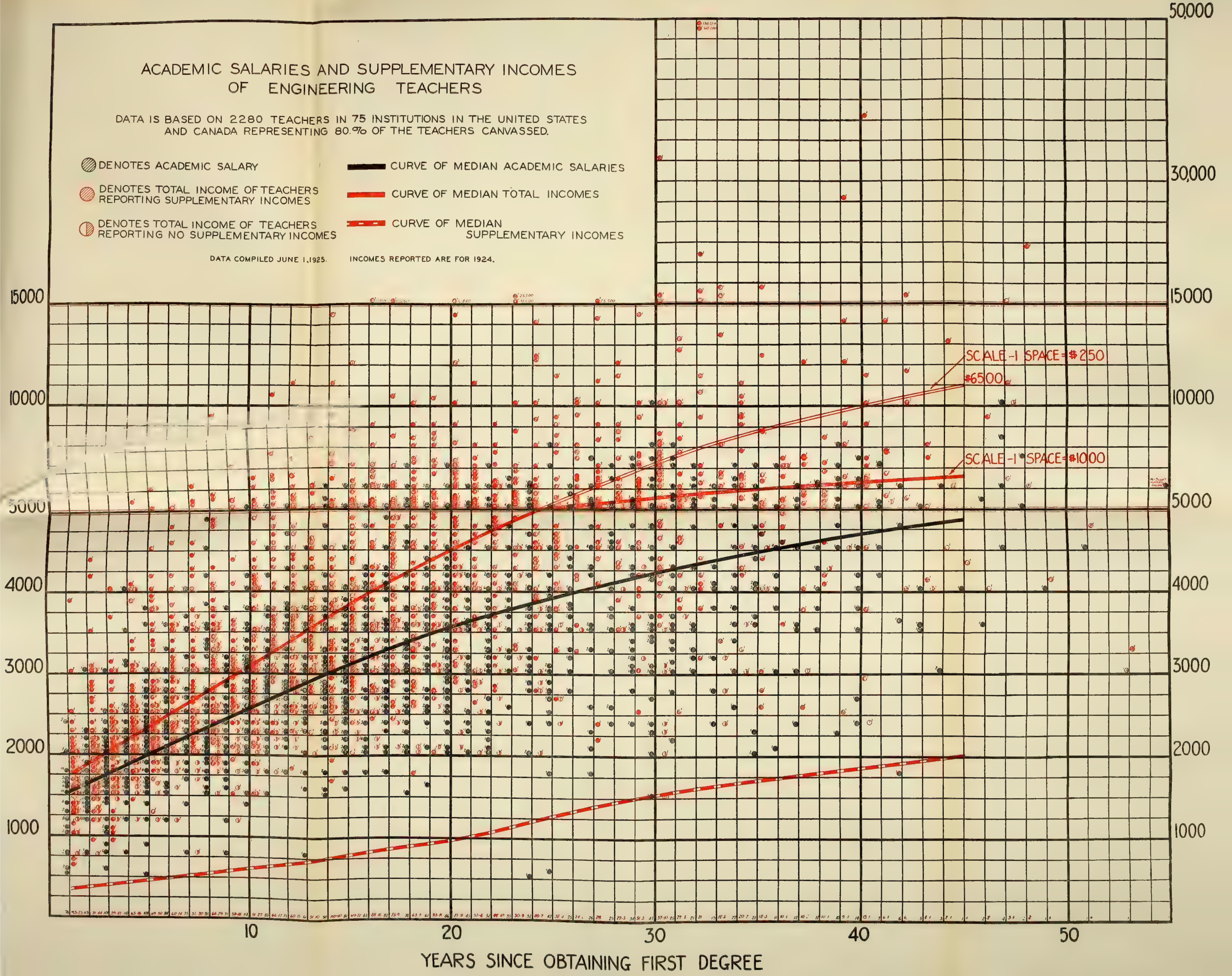
11. SUMMARY OF DEGREES HELD BY TEACHERS OF ENGINEERING STUDENTS.

(143 Institutions Included.)

Degrees.	Teachers of Engineering Subjects Including Mechanics.		Teachers of Chemistry and Chemical Engineering.		Teachers of Sciences, Including Mathematics.		Teachers of English and Modern Languages.		Teachers of Economics and Business.	
	No.	%.	No.	%.	No.	%.	No.	%.	No.	%.
Dr. Eng.	15	0.40	1	0.01	0	0.00	0	0.00	0	0.00
Dr. Sc.	66	1.79	43	2.83	66	2.65	3	0.12	3	0.29
Ph.D.	95	2.57	484	31.76	601	24.56	502	20.37	197	19.74
Professional degrees, C.E., E.E., M.E., etc.	1,086	29.40	41	2.68	131	5.24	5	0.21	22	2.20
M.S. with specification as M.S. in C.E.	109	2.95	12	0.78	11	0.35	1	0.05	1	0.10
M.S. without specification	245	6.64	267	17.49	254	10.12	17	0.69	23	2.30
B.S. with and without specification	1,113	30.14	199	13.09	267	10.71	70	2.85	73	7.39
A.B., Ph.B., etc.	232	6.28	186	12.18	487	19.85	791	32.09	250	25.03
M.A.	116	3.15	207	13.56	517	20.06	859	34.83	251	25.13
LL.D., Litt.D., etc.	19	0.51	14	0.91	47	1.87	53	2.15	24	2.42
Other degrees	76	2.06	48	3.14	72	2.96	121	4.90	138	13.82
No degrees	521	14.10	24	1.57	41	1.63	43	1.74	16	1.59
Total number of degrees	3,693		1,526		2,494		2,465		998	
Total number of teachers	3,159		1,086		1,852		1,835		666	

12. POLICIES OF INSTITUTIONS AS TO PARTICIPATION OF TEACHERS IN ENGINEERING PRACTICE DURING THE COLLEGE YEAR.

		State Universities.	Land Grant Colleges.	State Schools of Mines.	State Military Colleges.	Municipal Institutions.	Privately Endowed Universities.	Privately Endowed Polytechnic Institutes.	Privately Endowed Arts Colleges.	Canadian Institutions.	Hawaiian Institutions.	Totals.
Outside work permitted	No.	33	12	6	2	2	27	12	9	7	1	111
	%	*91.7*	*85.7*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*95.7*
Outside work not permitted	No.	3	2									5
	%	*8.3*	*14.3*									*4.3*
Outside work encouraged	No.	18	5	5	1	1	21	9	9	6	1	76
	%	*50.0*	*35.7*	*83.3*	*50.0*	*50.0*	*77.8*	*75.0*	*100.0*	*85.8*	*100.0*	*68.5*
Outside work tolerated	No.	14	6	1	1		6	2				30
	%	*38.9*	*42.9*	*16.7*	*50.0*		*22.2*	*16.7*				*27.0*
Outside work discouraged	No.	1	1			1						3
	%	*2.8*	*7.1*			*50.0*						*2.7*
Not answering	No.							1		1		2
	%							*8.3*		*14.2*		*1.8*
Number of institutions of each type		36	14	6	2	2	27	12	9	7	1	116



ACADEMIC SALARIES AND SUPPLEMENTARY INCOMES OF ENGINEERING TEACHERS

DATA IS BASED ON 2280 TEACHERS IN 75 INSTITUTIONS IN THE UNITED STATES AND CANADA REPRESENTING 80.% OF THE TEACHERS CANVASSED.

▨ DENOTES ACADEMIC SALARY

▨ DENOTES TOTAL INCOME OF TEACHERS REPORTING SUPPLEMENTARY INCOMES

◐ DENOTES TOTAL INCOME OF TEACHERS REPORTING NO SUPPLEMENTARY INCOMES

CURVE OF MEDIAN ACADEMIC SALARIES

CURVE OF MEDIAN TOTAL INCOMES

CURVE OF MEDIAN SUPPLEMENTARY INCOMES

DATA COMPILED JUNE 1, 1925. INCOMES REPORTED ARE FOR 1924.

50,000
30,000
15000
10000
5000
4000
3000
2000
1000
SCALE-1 SPACE=$250
$6500
SCALE-1 SPACE=$1000
10
20
30
40
50
YEARS SINCE OBTAINING FIRST DEGREE

13. LIMITATIONS AS TO AMOUNT AND CHARACTER OF OUTSIDE WORK.

NATURE OF LIMITATION.

	Number of Institutions
Outside work must be of a consulting nature only and must advance the teacher's professional standing	15
Permission of President or Trustees must be obtained	6
Permission of Dean or Director of Department must be obtained	8
Not less than two-thirds of teacher's time must be devoted to the institution	1
Teacher may give approximately one-eighth of time to outside work	1
There must be no direct competition with local practicing engineers (Municipal Institution)	1
Outside office must not be maintained	1
One-half of income derived from outside work goes to the institution	1

ARRANGEMENTS FOR USE OF LABORATORY EQUIPMENT BY TEACHERS IN CONNECTION WITH OUTSIDE WORK.

	Number of Institutions.
Materials, power, etc. used must be paid for	49
Fee is paid for use of laboratory	43
No specific arrangement	13
Use of laboratories not permitted	3
No reply	3

LIMITATION ON USE OF THE NAME OF THE INSTITUTION IN CONNECTION WITH OUTSIDE WORK.

	Number of Institutions
None, but the school is not responsible for the results	23
Professor may state his connection with the school	12
Professor must not state his connection with the school	65
No specific regulations, each case decided on its own merits, and miscellaneous replies	6
No reply	5

BULLETIN NUMBER 5
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF
THE SUPPLEMENTARY ACTIVITIES OF ENGINEERING COLLEGES—ORGANIZED RESEARCH, GRADUATE COURSES, EXTENSION COURSES, AND OTHER SERVICES

Conducted under the Auspices of the
Committee on Supplementary Services and Facilities
of the Engineering Colleges

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THE SUPPLEMENTARY ACTIVITIES OF ENGINEERING COLLEGES
GRADUATE COURSES, ORGANIZED RESEARCH, EXTENSION COURSES, AND OTHER SERVICES

Purposes.—The purpose of this study was to prepare an inventory of the services rendered by engineering colleges of the United States and Canada other than those connected with the regular, full-time undergraduate courses.

Sources of Data.—Information was obtained by means of questionnaires circulated to all colleges and schools of engineering of the United States and Canada which offer courses leading to degrees. In certain cases other data were obtained from catalogues and verified by correspondence. One hundred and fifty-one of the one hundred and sixty-four institutions supplied information. In the thirteen which did not, engineering is a very minor activity. It is believed, therefore, that the information given on the following pages is substantially complete. Every effort has been made to have it accurate.

Many services rendered by engineering colleges are of such a nature that they cannot be classified definitely or stated in quantitative terms. The tabulations which comprise the body of the results of the survey include most of the important services which can be expressed quantitatively. These fall into a number of classifications to each of which one tabulation has been devoted. Those services which cannot be expressed in this manner are commented upon.

Auspices.—The study was conducted under the sponsorship of the Committee on Supplementary Services and Facilities of the Engineering Colleges:

Harold Pender, *Chairman,* University of Pennsylvania,
Edward H. Rockwell, *Secretary,* Rutgers University,
C. M. Allen, Worcester Polytechnic Institute,
H. S. Evans, University of Colorado,

Anson Marston, Iowa State College,
C. R. Richards, Lehigh University.

The material which follows is based upon the report of the committee which was presented in June, 1926.

Summary of Results.—The results of the survey, taken as a whole, indicate that engineering colleges recognize that the needs of industry which the colleges are directly or indirectly in a position to supply extend far beyond undergraduate instruction. The tabulations include a variety of instructional work which aggregates a considerable total. As might be expected, the tax-supported institutions supply these supplementary services to a much greater extent than do the privately endowed colleges and universities. These activities are not, however, confined exclusively to the tax-supported institutions, and many of the privately endowed institutions report extensive supplementary activities. While no study has been made of the dates of establishment of the "supplementary" activities included in this survey, it is known that many activities of this character are of comparatively recent origin and that their growth is becoming progressively more rapid.

Organized Engineering Research and Testing.—Table 1 gives a summary of expenditures, personnel, and publications relating to engineering research and testing carried on under the direction of engineering colleges. The information was supplied in answer to a question as to whether the institution carried on organized research in the field of engineering other than that undertaken by individual members of the staff on their own initiative. If answered in the affirmative, this question was followed by a request for detailed data.

It will be noted that sixty institutions in the United States and four in Canada are listed. These institutions either have a definitely organized research division, or carry on research or testing work under the direction and control of the engineering department. In several cases, however, while there is provision for a research division, no expenditures have been made and no projects have as yet been undertaken. Only forty-three of the sixty institutions in the United States report expenditures for research in 1924–25, and but twenty-nine report expenditures of $5,000 or more per year. Seventy-five per cent of the total expenditures are reported by ten institutions and ninety per cent by twenty-two institutions. It is evident that the bulk of the research work in engineering is done in comparatively few colleges.

It should be noted that in a number of institutions there is much valuable research work done which is not undertaken under the direct supervision of the institution itself. At such institutions as Harvard, the University of Pennsylvania, the University of Pittsburgh, Columbia University, and several others, important contributions to knowledge through engineering research are made each year. Due to methods of organization and budgeting of expenses in such institutions, it is not possible to make a separation either of expenditures or of time spent by members of the staff in research. In this respect the table is incomplete. It is not possible to estimate the increments to the tabulation which would result if the research work of these institutions were included.

Limitations of Data on Research.—In studying the table it should be remembered that the word ''research'' is susceptible of different interpretations by different individuals and that it is often difficult to distinguish between genuine research and what may more properly be designated as development work or engineering testing. An effort was made to exclude testing of a purely routine character, but it is not certain that expenditures for some work of this kind are not included. It is quite possible that if the tabulation were limited to really fundamental research, the figures might be appreciably smaller.

It is apparent also that the data given by the various institutions are not directly comparable, due in large part no doubt to different interpretations of the questions asked. For example, one institution reports a research staff of three full-time men, and yet reports no funds for research. Another institution reports a total of $139,000 expended for research during the year 1924–25, and a staff of fifty-two full-time men, but reports no publications to date and no projects under way in June, 1925. On the other hand, another institution, with approximately the same research budget, reports eighty-five research projects under way on June 1, 1925. In spite of these inconsistencies, all of which could not be eliminated, the combined data serve to indicate the extent of the research activities of the engineering colleges.

Summary of the Research Situation.—For the institutions listed in the table the total amount expended during the year 1924–25 on engineering research was $1,304,132. Including institutions, such as Harvard, University of Pennsylvania, Princeton, Yale, etc., which report no separate research organizations, this total would probably reach $1,500,000. This, compared with the $30,000,000 expended annually for undergraduate engineering training, indicates that at the present time engineering colleges are devoting about five per cent of their annual income to engineering research and tests.

In view of the importance of engineering research to the industries, both directly and through the training of research workers and competent engineering teachers, this annual expenditure of $1,500,000, although seemingly large in the aggregate, is entirely inadequate. At least four industrial concerns each exceed this sum in their annual expenditures for research.

It may also be concluded from the tabulation that relatively few institutions are carrying on engineering research on an extensive scale, and that there are no organized research activities whatever in about two-thirds of the engineering colleges.

Graduate Courses.—Graduate courses in engineering are offered by more than half of the institutions in the United States, as shown by Table 2. The number in which there are enrollments, however, is slightly smaller—seventy-seven institutions. It is to be noted that seven-eighths of the total enrollment is in ten institutions. One institution alone has twenty per cent of all of the graduate students in engineering.

The ratio of enrollments in graduate courses for 1924–25 to the number of graduates obtaining first degrees in 1924, is approximately twelve per cent. This seems to be a reasonable proportion. The ratio of the number of advanced degrees to first degrees is approximately seven per cent.

A careful study of the returns indicates that in a considerable number of the colleges the courses offered are largely on paper and that actually the graduate work is not on a definite going basis.

Graduate Degrees.—Of the 522 advanced degrees shown in Table 3 as granted in 1925, only eight were of the grade of doctor, the others being the degree of master or equivalent. This indicates clearly that practically all the graduate instruction in engineering consists of a single year's work superimposed upon the usual four-year undergraduate curriculum. It is also probable that in many instances this fifth year of so-called graduate work is merely an extension of the undergraduate curriculum to cover certain special topics for which there is not sufficient time in the regular four-year course. Real advanced instruction in the fundamentals of engineering is given in only a very few institutions. This is evidenced by the fact that most of the research workers in the large commercial laboratories are recruited, not from the engineering colleges, but from the graduate departments of physics and chemistry. In fact there are relatively few teachers of engineering who have had the fundamental training in mathematics, physics and chemistry to qualify them to give the type of graduate instruction needed by those who wish to prepare themselves specifically for high-grade engineering research.

In connection with the tabulation of advanced degrees it is to be noted that these are degrees granted for work in residence only and that professional degrees conferred on the basis of practical experience plus a thesis are not included. Advanced degrees conferred by graduate schools are included where it is clear that the work may properly be classified as engineering as distinguished from pure science.

Fellowships in Engineering.—Of the 150 institutions which supplied information, fifty-two offer one or more fellowships in engineering. The total number of fellowships offered in 1924–1925 was 227, but of these 163, or 72 per cent, are really half-time teaching positions. Only sixty-eight unencumbered fellowships for full time graduate study in engineering are offered. It appears that the much needed advanced study in engineering could be greatly stimulated by the offering of a greater number of such fellowships.

The average stated stipend of the fellowships offered is $585, which is approximately half the average salary of a first-year instructor or assistant. It is to be noted that the stipends listed do not include amounts remitted for tuition fees. Had these been included, the stipends would have been considerably larger in many cases. They were not included for the reason that in many institutions the tuition fees are virtually nominal and, therefore, do not represent actual values.

Evening Courses Leading to Degrees.—Only six institutions offer evening courses in engineering *which lead to degrees.* Four of these are situated in New York City, one in Washington, and one in Pittsburgh. It is evident that provision for work of this character is not well distributed in the large centers of population.

That the same degree should be awarded for evening work as for the regular day courses may perhaps be doubted by some. To others it seems entirely feasible to provide adequate safeguards to insure the full equivalence of such evening work with the work done in the regular full-time program, and that when such precautions are taken the evening student should receive the same recognition as the attendant of the day classes.

Two general classes of students offer themselves for these courses. One class includes high school graduates who are unable for financial reasons to attend regular day classes. The other class includes the graduates and former students of engineering who wish either to take additional work or to complete their college course. Many of the latter are students who were obliged to leave college in order to earn a living.

It is the experience of institutions offering work of this character that the students are earnest and purposeful and that the classes are conducted in an atmosphere and with a spirit which are very impressive. The total enrollments in 1924–25 in the colleges which offer evening courses leading to degrees was approximately 3500 and the number of degrees conferred was 133.

It is a fair question to ask whether more work of this character could not be offered with advantage in the large industrial centers of the country. However, when funds are limited and the evening classes can not be made self-supporting, it is doubtful if such evening courses should be undertaken.

Evening Courses Not Leading to Degrees.—Twenty-one institutions offer work in engineering in the evening which does not lead to degrees. There is considerable diversity in both the type and character of this work, ranging as it does from graduate work to that of a purely vocational character. The institutions offering the work are for the most part located in large centers of population. On the other hand, there are many institutions located in large cities which offer no evening courses whatever. The twenty-one institutions all offer degrees in engineering in their regular day courses. None of the institutions such as Pratt Institute, Wentworth Institute, Franklin Union, Ohio Mechanics Institute, etc., which do not offer degrees for either day work or evening work, is included. The summary therefore does not give a complete picture of the provision in the evening for technical work of an intermediate character.

Provision for instruction in engineering and vocational work of the types listed in the table is a distinctly necessary and valuable educational work. Whether or not it is a proper function of the engineering colleges themselves may be open to question. However, it is worth noting that in the entire country there are but ten non-degree-granting institutions of a substantial character, such as those named in the preceding paragraph, which provide training of this type (excluding proprietary schools). This very significant fact should not be lost sight of in any discussion of this particular phase of engineering education.

Short-term and Special Courses in Residence.—Thirty-one institutions offered short-term and special courses in residence in 1924–25 and the total enrollment in such courses was 3307. The courses vary widely in type, ranging all the way from short intensive courses for graduates or practicing engineers to those of a distinctly vocational character. The many titles of the courses are indicative of this. The institutions offering them are quite widely distributed geographically. A majority of them are publicly supported institutions.

Requirements for admission to short-term courses vary widely, but for the most part they are open to students having less than a complete high school training. In some cases, certificates are awarded upon completion of the work; in others, no credentials of any sort are given.

Eight institutions offer extra-mural courses. With the exception of a single institution, the enrollments in such courses are small. One institution offers a graduate extra-mural course. In the other institutions most of the extra-mural work is of a vocational character.

Correspondence Courses.—While sixteen institutions offer correspondence courses, practically all the registrations were reported by one institution. It is apparent that the engineering colleges have not embarked extensively on work of this character. Most of the subjects offered by correspondence are those of the first two years in engineering although some additional work of a more strictly technical character is provided for. The University of Wisconsin was a pioneer among the collegiate institutions in this work and has developed it to a much greater extent than any of the others. Some of the correspondence work is accepted toward the degree, but in no institution is the degree conferred for work in correspondence exclusively.

Other Services Rendered by the Colleges of Engineering.—In addition to the activities outlined in the foregoing paragraphs, the colleges supplied information regarding a number of other supplementary activities.

a. Of the 151 institutions reporting, 110 stated that individual members of the teaching staffs were engaged in engineering research on their own initiative or under the direction of the institution. This includes the institutions previously mentioned. It is significant to note that in forty-one institutions conditions are such that individual teachers do not engage in research.

b. Of the 151 institutions, 117 reported that routine engineering tests are conducted either by or in the name of the institution by individual members of the staffs. Thirty-four institutions reported that no work of this character is done. This number is approximately the same as the number reporting that no research work is done, and it is apparent that in a considerable fraction of the institutions undergraduate instruction constitutes practically the sole activity.

c. In a very few institutions there are definitely organized plans through which the services of the engineering staffs are made available in consulting capacities to the industries, public service utilities, departments of the state or municipality, or to others.

d. In addition to the foregoing activities, many of the engineering colleges, or members of their staffs, have definite connections with, or serve as members of, state or city commissions, boards of trade, engineering and industrial commissions, etc. Teachers of engineering are largely represented in the activities of the professional engineering societies, both in their governing bodies and in their technical committees. The colleges or individuals also act directly or in an advisory capacity in the educational work of industrial establishments. In a number of cases the colleges also compile and distribute data regarding the natural resources and the industries of the states, and are active in developing those resources. It is, of course, not possible to list the many additional activities such as the rendering of expert testimony, connection with numerous civic and state activities, and the like. Twenty of the institutions through their engineering departments maintain radio broadcasting stations and in some cases regular courses of instruction are given in this manner.

1. ORGANIZED ENGINEERING RESEARCH AND TESTING—1924 AND 1925.

Institutions in the United States.	Name of Department Devoted to Research.	Date Established.	Annual Engineering Research Funds.			Engineering Research Staff, All Grades.			Number of Publications Issued to June 1, 1925.	Number of Projects in Progress, June 1, 1925.
			Appropriation by the State.	Allotted by the College.	Funds from Other Sources.	Full Time.	Compensation in Part from Research Funds.	Part Time without Extra Pay.		
Alabama, University of	United States Bureau of Mines, Southern Experiment Station.	1919				3		2		3
Arizona, University of	Arizona Bureau of Mines......	1915		25,530		3	6		118	4[a]
Arkansas, University of	Engineering Experiment Station	1920		5,700		1		4	1	3
California Institute of Technology	No Separate Department......			70,000	69,000	52				
Carnegie Institute of Technology	Bureau of Metallurgical Research....................	1924		17,000		3	1		6	5
Cincinnati, University of	Institute of IndustrialResearch	1925			75,000	15	20			
Clemson Agricultural College[b]	Engineering Experiment Station	1924		2,000				3		2
Colorado Agricultural College[c]	Engineering Section of General Experiment Station.........	1918	10,900			3	4		5	5
Colorado School of Mines	Department of Metallurgy and Research.................	1912		28,820[d]		4				
Cornell University	Engineering Experiment Station	1923		7,000		3	3	8	288	
Florida, University of	No Separate Department......				400					3
Georgia School of Technology	Department of Research and Tests....................	1922	3,500			1	2		5	
Idaho, University of	No Separate Department......			1,000				1		
Illinois, University of	Engineering Experiment Station	1903		105,056	55,500	28	18	50[e]	167	85
Iowa State College	Engineering Experiment Station	1904	45,000	13,000	18,400	13	29	9	72	40

[a] All geological investigations considered as one project.

[b] Project is a materials survey of the State.

[c] All figures are for the Engineering Section.

[d] "State funds but out of our General Fund."

[e] Estimated.

1. ORGANIZED ENGINEERING RESEARCH AND TESTING—1924 AND 1925.—*Continued.*

Institutions in the United States.	Name of Department Devoted to Research.	Date Established.	Annual Engineering Research Funds.			Engineering Research Staff, All Grades.			Number of Publications Issued to June 1, 1925.	Number of Projects in Progress, June 1, 1925.
			Appropriation by the State.	Allotted by the College.	Funds from Other Sources.	Full Time.	Compensation in Part from Research Funds.	Part Time without Extra Pay.		
Iowa, State University of	Research in Hydraulics and Radio	1921	7,000		9,410[f]	3		4	3	9
Johns Hopkins University	No Separate Department			10,000	15,000	3		7	145	8
Kansas State Agricultural College	Engineering Experiment Station	1910		12,250		2	4	25	15	2
Kansas, University of	Engineering Experiment Station	1908		1,450	1,300		1	1	12	3
Kentucky, University of	No Separate Department			3,000		1				3
Lafayette College	No Separate Department				3,500				47	6
Lehigh University	Institute of Research of Lehigh	1924					2	1	3	28
Lewis Institute	Structural Materials Research Laboratory	1914			120,000[g]	40			18	25
Maine, University of	Engineering Experiment Station	1915	2,575			1	5	6	13	14
Maryland, University of	Engineering Experiment Station	1921		3,500	3,500		5	4		
Massachusetts Institute of Technology	Six Divisions of Research	1903		75,000	100,000	23	26		354	
Michigan State College	Engineering Experiment Station	1924		8,000		1	3	5		12
Michigan, University of	Department of Engineering Research	1920		10,000	60,601	8	94			60
Minnesota, University of	Engineering Experiment Station	1921		4,250			2[h]	15[i]	7	22
Missouri School of Mines	State Mining Experiment Station	1909	25,000		25,000[j]	5	4		28	1

[f] U. S. Department of Agriculture and Bureau of Public Roads.

[h] Portland Cement Association.

[h] Two half-time. Several by the hour.

[i] Estimated.

[j] United States Government.

1. ORGANIZED ENGINEERING RESEARCH AND TESTING—1924 AND 1925.—*Continued.*

Institutions in the United States.	Name of Department Devoted to Research.	Date Established.	Annual Engineering Research Funds.			Engineering Research Staff, All Grades.			Number of Publications Issued to June 1, 1925.	Number of Projects in Progress, June 1, 1925.
			Appropriation by the State.	Allotted by the College.	Funds from Other Sources.	Full Time.	Compensation in Part from Research Funds.	Part Time without Extra Pay.		
Missouri, University of	Engineering Experiment Station	1909	5,000				3	4	24	6
Montana State College	Engineering Experiment Station	1924								
Nebraska, University of	Engineering Experiment Station	1923			14,480	3	7	4		5
Nevada, University of	Engineering Experiment Station	1921		250				6	2	1
New York University	No Separate Department......				18,000	2	8			30[k]
North Carolina State College of Agriculture and Engineering	Engineering Experiment Station	1923		28,000		1	2	13		14
North Carolina, University of	No Separate Department......		7,500		7,500					1
North Dakota, University of	Mining Experiment Station....	1905	11,553	3,325	5,000[l]	2	12		25[l]	4
Ohio State University	Engineering Experiment Station	1913	10,000		1,000	4	28	17	44	20
Oklahoma, University of	Petroleum Engineering Course.	1924			500			1		2
Pennsylvania State College	Engineering Experiment Station	1908		15,780	500	6	2	8	36	6
Purdue University	Engineering Experiment Station	1917	24,890		49,200	14[m]	5	6	25	16
South Carolina, University of	Engineering Experiment Station	1924		2,000			3	3		
South Dakota State School of Mines	Mining Experiment Station....	1913	3,750			1	1			
Stanford University	High Voltage and Aerodynamics Laboratories............	1916			1,662	2	5	19	9	20

[k] 25–30.

[l] Estimated.

[m] In addition, 30 men are employed on investigations in cooperation with the American Railway Association.

1. Organized Engineering Research and Testing—1924 and 1925.—*Continued.*

Institutions in the United States.	Name of Department Devoted to Research.	Date Established.	Annual Engineering Research Funds.			Engineering Research Staff, All Grades.			Number of Publications Issued to June 1, 1925.	Number of Projects in Progress, June 1, 1925.
			Appropriation by the State.	Allotted by the College.	Funds from Other Sources.	Full Time.	Compensation in Part from Research Funds.	Part Time without Extra Pay.		
Stevens Institute of Technology	Physics Research Department .	1925			1,000					1
Tennessee, University of	Engineering Experiment Station	1921		1,000			1	5	7	1
Texas, Agricultural and Mechanical College of	Engineering Experiment Station	1914	2,000				1	2	30	3
Texas, University of	Engineering Experiment Station	1914	725	725		2	2		7	3
Utah, Agricultural College of	Agricultural Experiment Station	1918					2			4
Utah, University of	Engineering Experiment Station	1918	12,500	1,650	2,500[n]	3		6	16	4
Vermont, University of	Engineering Experiment Station	1922		1,500						
Virginia Polytechnic Institute	Engineering Experiment Station	1921		1,400			2	7	1	4
Washington, State College of	Engineering Experiment Station	1911[o]		5,000		1	1	5	16	4
Washington, University of	Engineering Experiment Station	1917	6,500				10[p]		32	12
Washington University	No Separate Department......						1	7		8
West Virginia University	Engineering Experiment Station	1921		6,000	600		3	10	2[q]	10
Wisconsin, University of	Engineering Experiment Station	1914		6,000			3	10	54	
			178,393	467,186	658,553	257	331	278		
Totals—For Institutions in the United States..............			$1,304,132			866			1637	522

[n] Plus maintenance of buildings and a fellowship at $500.

[o] As a separate department in 1919.

[p] Time allowance, not cash, for research.

[q] Also 10 mining semi-research bulletins.

1. ORGANIZED ENGINEERING RESEARCH AND TESTING—1924 AND 1925.—*Continued.*

Institutions in Canada.	Name of Department Devoted to Research.	Date Established.	Annual Engineering Research Funds.			Engineering Research Staff, All Grades.			Number of Publications Issued to June 1, 1925.	Number of Projects in Progress, June 1, 1925.
			Appropriation by the State.	Allotted by the College.	Funds from Other Sources.	Full Time.	Compensation in Part from Research Funds.	Part Time without Extra Pay.		
Alberta, University of	Scientific and Industrial Research Council	1919	54,832[r]			11	5		10	4
McGill University	No Separate Department						2	12		
Nova Scotia Technical College	No Separate Department			500	2,000					
Queen's University	No Separate Department			1,000		1			6	8
Saskatchewan, University of	No Separate Department			15,000		2		15		20[s]
Toronto, University of	School of Engineering Research	1917	22,800		1,000	2	11		5[t]	14
			77,632	500	3,000	16	18	27		
TOTALS—For Institutions in Canada			$97,132			61			21	46
GRAND TOTALS—For Institutions in the U. S. and Can.			$1,401,264			927			1,658	568

Note: In several institutions in which research is done, there is no separate administrative organization for directing it and expenditures are not carried as a separate budget item. Such institutions are not included in the above table but are listed as follows: Harvard University, Columbia University, University of Pittsburgh, University of Pennsylvania, Princeton University, Yale University, Rensselaer Polytechnic Institute, and Worcester Polytechnic Institute.

[r] Supported by Provincial Government.

[s] Approximate.

[t] Contain 73 papers.

2. Graduate Courses in Engineering.

Institutions which offer Graduate Courses in Engineering	81
Institutions which do *not* offer Graduate Courses in Engineering	68
Institutions not replying	2
Total	151

Graduate Courses Offered.	Number of Institutions Offering Each Course.	Number Reporting 1924–1925 Enrollments in Each Course.	Total Enrollments in 1924–1925.
Chemical Engineering	44	17	156
Electro-Chemical Engineering	1	1	4
Ceramic Engineering	3	0	0
Oil Refining	1	0	0
Gas Engineering	1	0	0
Civil Engineering	58	23	98
Highway Engineering	2	0	0
Hydraulic Engineering	1	0	0
Municipal Engineering	1	0	0
Railway Engineering	2	0	0
Sanitary Engineering	6	3	9
Structural Engineering	2	0	0
Architectural Engineering	12	2	3
Electrical Engineering	59	21	232
Mechanical Engineering	57	20	92
Aeronautical Engineering	2	1	14
Marine Engineering	1	0	0
Flour Mill Engineering	1	0	0
Engineering Administration	1	1	3
Industrial Engineering	2	0	0
Mining Engineering	24	10	57
Metallurgical Engineering	12	6	13
Geology and Mineralogy	1	0	0
Oil and Gas Production	1	0	0
General Engineering	4	2	15
General Science	1	0	0
Agricultural Engineering	7	2	12
Forest Engineering	1	0	0
Textile Engineering	1	0	0
Trades and Industries	1	1	6
Unclassified	3	2	32
TOTALS	81	77	746 (49 Inst.)
TOTAL—Unclassified Enrollments			256 (28 Inst.)
GRAND TOTAL			1,002 (77 Inst.)

3. ADVANCED DEGREES IN ENGINEERING.

Degrees Offered.	Number of Institutions Offering Each Degree.	Number Reporting Degrees Granted in 1924–25.	Total Number of Degrees Granted in 1924–25.
Doctor of Philosophy	18	2	7
Doctor of Science	5	1	1
Doctor of Engineering	2	0	0
Master of Arts	1	1	7
Master of Arts in Agri. Eng'g	1	0	0
Master of Science	38	21	212
M. S. with Designation	29	23	194
Master of Architecture	3	1	2
Master of Chemical Engineering	2	1	1
Master of Civil Engineering	4	1	5
Master of Electrical Engineering	4	2	7
Master of Gas Engineering	1	0	0
Master of Mechanical Engineering	4	2	13
Master of Science in Engineering	4	3	25
Master in Architecture	1	0	0
Master in Architectural Eng'g	1	0	0
Master of Applied Science	2	2	16
Agricultural Engineer	2	0	0
Architectural Engineer	1	1	1
Chemical Engineer	8	2	3
Civil Engineer	16	7	14
Electrical Engineer	14	8	13
Mechanical Engineer	14	7	23
Metallurgical Engineer	3	0	0
Engineer of Mines	4	1	3
Engineer in ————	1	1	25
TOTAL—Degrees	81	60	572 (60 Inst.)

Professional degrees such as C.E., E.E., etc. conferred on the basis of practical experience plus a thesis are not included in these summaries, but only degrees conferred for work in residence.

4. Fellowships Available to Graduate Students of Engineering.

Institutions which offer fellowships in engineering	52
Institutions which do not offer fellowships in engineering	98
Institutions not replying	1
Total	151
Institutions which did not supply detailed information	4

Department or School in Which Offered.	Number of Institutions in Which Offered.	Total Number Offered in 1924–25.	Total Number Held in 1924–25.	Stated* Average Yearly Stipend.	Teaching and Research Work Required.
Chemical Engineering	15	26	26	$575	11 fellowships require none, others from 6 to 12 hours per week.
Civil Engineering	14	23	20	603	5 fellowships require none, others about ½ time.
Electrical Engineering	20	32	29	610	6 fellowships require none, others about ½ time.
Mechanical Engineering	15	32	24	550	9 fellowships require none, others about ½ time.
Mining and Metallurgical Engineering	13	49	48	688	29 fellowships require none, others about ½ time.
Architectural Engineering	4	7	3	683	About ½ time.
Other Engineering	10	14	14	598	About ½ time.
Not by Department or School	8	44	42	520	4 fellowships require none, others about ½ time.
TOTALS		227	206	Weighted Average $585	

Total fellowship funds available to graduate students of engineering, 1924–1925 .... $120,000

* Some of the above fellowships carry remission of tuition fees, in part or entirely, but the cash values of these have not been reported.

5. EVENING COURSES IN ENGINEERING LEADING TO DEGREES.

Course Offered.	Number of Schools Offering Each.	1924–25 Enrollment.	Degrees Offered.	Number of Schools Offering Each.	Number of Degrees Granted 1924–25.
Civil Engineering	6	661	B.S. in C.E.	4	26
			C.E.	3	4
Chemical Engineering	5	285	B.S. in Ch.E.	3	18
			Ch.E.	3	3
Chemistry	3	174	B.S. in Chem.	3	6
Electrical Engineering	6	844	B.S. in E.E.	4	27
			E.E.	3	3
Industrial Engineering	1	12	B.S. in I.E.	1	0
Mechanical Engineering	6	750	B.S. in M.E.	4	38
			M.E.	3	5
Metallurgical Engineering	1	48	B.S. in Met. Eng.	1	2
Physics	1	8	B.S. in Physics	1	1
Students not Classified by Departments	3	698			
TOTALS..............	6*	3480			133**

* No students have been graduated from two of the institutions since the evening courses have been recently organized.

** This total does not include 15 graduates whose classification could not be determined.

6. EVENING COURSES IN ENGINEERING NOT LEADING TO DEGREES.

Twenty-one institutions offer evening courses in their engineering departments which do not lead to degrees.

Twenty of these institutions supplied detailed information regarding this work. Fifteen formally recognize the completion of courses; fourteen by awarding certificates and one by awarding diplomas. In three institutions certain certificates are given only upon completion of from one and one-half to three years of work.

Admission requirements vary with the subject to be pursued. In some cases they are determined by each instructor; and in a few cases there are no requirements for admission other than ''ability to pursue the desired subject.''

Five institutions report either no admission requirements or that less than a high school education is required.

Total enrollment in non-degree, evening courses in engineering during 1924–25	9,053
Total enrollment in institutions granting certificates, 1924–25	7,688
Total number of certificates conferred during 1923–24	1,110*
Enrollment in ''diploma'' courses, 1924–25	906
''Diplomas'' granted in 1923–24	139

(* In some cases certificates are given only upon request.)

The following courses and subjects in which certificates or diplomas are awarded were reported:

Civil Engineering
Structural Engineering
Surveying
Graphic Statics
Municipal Engineering
Specifications
Architecture
Architectural Design
Architectural Drawing
Architectural Engineering
Building Construction
History of Architecture
Chemical Engineering
Electrical Engineering
Electricians' Course
Applied Electricity
Practical Electricity
Short Meter Course
Advanced Radio Engineering
Mechanical Engineering
Industrial Engineering
Machine Design
Machine Tools
Mechanism
Auto Mechanics
Heating and Ventilation
Machine Shop Practice
Methods of Apprentice Training
Foremanship
Mining Engineering
Blue Print Reading
Descriptive Geometry
Shop Arithmetic
Mechanical Drawing

7. Short Term Courses Offered by Engineering Colleges in Residence.

Courses Offered.	No. of Institutions Offering Each.	1924–25 Enrollment.
Chemical Engineering	2	1
Metallurgy, Mining and Assaying	8	116
Electrical Course (2 years)	2	24
Electrical Repair, etc.	5	39
Electrical Metermen's Course	12	580
Telephone Plant and Repairs	3	86
Mechanical Engineering (2 years)	2	15
Machine Shop	2	21
Auto Mechanics and Auto Operation	8	152
Gas Metermen's Course	5	219
Draftsmen's Course	2	14
Highway Engineering, Roadmaking, etc.	7	867
TOTAL		2134

Courses Offered. (In one Institution only.)	1924–25 Enrollment.	Courses Offered. (In one Institution only.)	1924–52 Enrollment.
Applied Surveying (2 years)	7	Textile Engineering	8
Land Surveying, Short Course	7	Marine Engineering	0
Structural Engineering (2 years)	12	Stationary Engineering	0
Civil Engineering	0	Machine Design	0
City Planning (2 day conference)	50	Power Machinery (21 weeks)	48
Clayworking and Ceramics	61	Industrial Organization and Management	17
Ceramic Engineering	0	Power Plant Operators (3 days)	30
Marble Setters' Apprentice School	23	Ice Making and Refrigeration (2 days)	45
Industrial Group Round-up (2 days)	284	Operating (steam) Engineers (3 day conference)	200
Furniture Manufacturers' School (1 week)	15	Shop and Drawing Teachers (2 day conference)	50
Carpentry (12 weeks)	4	Mine Foremanship	11
Cotton Classing and Marketing	62	Colliery Engineering	0
Federal Trainees (2 years)	60	Blacksmith Trade Course (12 weeks)	6
Plumbers' Short Course	55	Blacksmith Trade Course (1 year)	9
Line Foremen (2 day conference)	107	Foundry Trade Course (1 year)	2
TOTAL	747	TOTAL	426

Institutions offering short term and special engineering courses in residence	31
Total enrollment in short term and special engineering courses in residence	3307

8. Extra-Mural Courses in Engineering.

Courses Offered.	No. of Institutions Offering Each.	1924–25 Enrollment.	Conferred on Completion.
Graduate Study in Metallurgy	1	9	Graduate Degree
Metermen's Course	2	59	Certificate
Auto Mechanics (Elementary and Advanced)	1	28	Certificate
Elements of Factory Management	1	109	Certificate
Foreman Training	1	0	Certificate
Heat Treatment of Iron and Steel	1	1,293	Certificate
Power Plants	1	49	Certificate
TOTALS	8	1,547	

Typical Admission Requirements:

''Usual education, high school or less.''

''Open to anyone interested in this subject.''

''Open to foremen, factory executives and others interested in factory problems.''

9. Correspondence Courses and Curricula in Engineering.

Sixteen institutions offer instruction by correspondence in engineering or in subjects required in the regular undergraduate engineering curricula.

During the spring of 1925, 6,171 active registrations in correspondence work were reported. Of these, 5,672 were reported by one institution. The next largest registration was 175. These registrations are by subjects rather than by curricula.

Six institutions offer a small amount of work by correspondence for college credit. Certificates are granted for completion of subjects or courses in institutions representing 5,777 of the total registration.

Over 200 subjects are catalogued under the following general headings:

Mathematics
Electrical Engineering
Structural Engineering
Drawing

Mechanical Engineering
Civil Engineering
Industrial Engineering

BULLETIN NUMBER 6
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF
THE COSTS OF ENGINEERING EDUCATION

Conducted under the Auspices of the
Committee on Supplementary Services and Facilities
of the Engineering Colleges

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THE COSTS OF ENGINEERING EDUCATION.

Purposes and Method.—The purposes of this study were to determine the costs of engineering education as accurately as possible; to express them in comparatively simple units; to determine the sources from which engineering colleges derive their revenues; and to determine the purposes for which funds are expended and the relative amounts expended for the several purposes.

Data on costs were obtained by means of questionnaires sent to all institutions of the United States and Canada which offer engineering curricula leading to degrees. Two such questionnaires were circulated, one during the year 1924–25 and the other during the year 1925–26. The first questionnaire was used in a preliminary way to obtain a rough idea of costs and to furnish experience upon which to base a more extended and thorough study to be carried out by means of the second questionnaire. Experience has demonstrated that it is impracticable to obtain figures from any considerable number of institutions on a uniform basis in greater detail than given herein. Every effort has been made to have the data on a strictly comparable basis and the scrutiny to which they have been subjected makes it reasonably certain that those which were retained for use are sufficiently uniform for present purposes.

Auspices.—The study was conducted under the sponsorship of the Committee on Supplementary Services and Facilities of the Colleges of Engineering:

Harold Pender, *Chairman,* University of Pennsylvania,
Edward H. Rockwell, *Secretary,* Rutgers University,
C. M. Allen, Worcester Polytechnic Institute,
H. S. Evans, University of Colorado,
Anson Marston, Iowa State College,
C. R. Richards, Lehigh University.

Two reports on costs have been presented by the committee, one in June, 1925, based upon the preliminary study, and one in June, 1926, based upon the more thorough analysis. The second of these reports comprises the material which follows. The actual work of collecting and compiling the data and of writing the reports was done largely by Dean Edward H. Rockwell, secretary of the committee, who carried out the task as a special assignment.

* * * * * *

Sources of Information.—Fifty-five different institutions supplied usable information on costs. They are classified as follows:

Privately Endowed Polytechnic Institutes	9
Privately Endowed Universities	11
State Universities, including some Land Grant Institutions	16
Land Grant Colleges	7
State Schools of Mines	5
Miscellaneous institutions, including two Municipal Institutions, one partially state-supported Institute of Technology, one Military College, one Sectarian College, two colleges offering the junior and senior years only of engineering curricula	7

These institutions have not in all cases given complete information and it should be noted that the number of institutions and the corresponding number of students are not the same for computations summarized in the several tables. The number of engineering students registered in institutions included in the tables is in general about 22,000, there being 24,172 in the institutions of Table 1, or about forty-four per cent of the total number in the United States. The data are therefore believed to be sufficiently representative.

All of the information regarding costs was originally gathered together on one large chart, each institution being listed in one of the above classifications. The totals on this chart were then analyzed in tables devoted to particular subjects as follows:

Table 1. Investment Devoted to Engineering Education.
Table 2. Sources and Amount of Income for Engineering Education.
Table 3. Expenditures for Engineering Education and Unit Costs per Student per Year and per Graduate.

These tables with graphical representations of the information contained in them constitute the substance of the results of this study.

Costs in Endowed Polytechnic Institutes.—It was stated in the preliminary report of June, 1925 that the most trustworthy results were those for the polytechnic institutes and institutes of technology, and this is also true for the present tabulations. This fact results from the difficulty of segregating the costs of engineering education in institutions which include other divisions of instruction. A comparison of these final results with those of the earlier report for this type of institution is as follows:

COSTS IN ENDOWED POLYTECHNIC INSTITUTES

	Report of 1923–24 Excl. Int. on Plant.*	Report of 1924–25.	
		Excl. Int. on Plant.	Incl. Int. on Plant.
Maximum cost per student per year	$ 625	$ 712	$888
Minimum cost per student per year	384	264	384
Average cost per student per year	551	571	750
Maximum investment per student	14,000	14,250	
Minimum investment per student	2,120	4,000	
Average investment per student	7,854	10,750	

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* The term "plant" signifies physical plant including land, buildings and equipment.

Comparison of Unit Costs by Types of Institutions.—A comparison of the average unit costs for five types of institutions given in the preliminary and final reports is as follows:

COMPARATIVE COSTS PER STUDENT

	Report of 1923–24 Excl. Int. on Plant.	Report of 1924–25.	
		Excl. Int. on Plant.	Incl. Int. on Plant.
Endowed Universities	$582	$582	$742
Endowed Polytechnic Institutes	551	571	750
State Universities	358	399	474
Schools of Mines	552	595	738
Land Grant Colleges	298	385	437

In the preliminary report no effort was made to determine the effect of ''interest on non-productive plant'' on the unit costs. The present report is based on complete data in relation to the value of plant which are in large part for July 1, 1925. In general there is a decided tendency toward undervaluation of plant and any costs including interest on plant are certainly below rather than above actual values.

Comparison with Non-Engineering Courses.—The following table shows the reported costs per student per year in courses other than engineering. Probably in no case do these figures include interest on plant. The costs for engineering students in these institutions are also given for comparison.

Cost per Student per Year in Courses Other than Engineering, in Dollars.

Key No. of Institution.	Agriculture.	Architecture.	Business Admin.	Chemistry.	Education.	Liberal Arts.	Law.	Medicine.	Cost in Engineering Excl. Int. on Plant.	Classification of Institution.
11						258	683	955	340	Municipal Institution.
14	304			300	300				303	Land Grant College.
16			281	281	281	281	383	1,152	418	State University.
26		200		200					354	Partially State-Supported Institute of Technology.
31	472		170		254	199	302	299	440	State University.
37	401		300		385	300	400		284	State University.
39			370			454			569	Privately Endowed University.
44							90	399	347	State University.
49	453	428		384		209	257	461		State University.
62			94		164	493	87	473	699	Privately Endowed University.
74	487		200		215				368	Land Grant College.
80						593			593	Privately Endowed University.
107		268			155	186	250		511	State University.
113									336	State University.
204			605			544		928	1,552	Privately Endowed College of Engineering in Graduate School.
215			264						384	Privately Endowed Polytechnic Institute.
258					250	250	214	500	383	State University.

Data on Investment in Plant and Endowments.—Table 1 contains the summary of the data in relation to investment in engineering education and gives information for forty-five institutions with 24,172 engineering students classified in accordance with the type of institution.

The table contains first, the investment as reported on the questionnaires. For all of the institutions except the institutes of technology and the schools of mines, the data pertains *only to that part of the plant distinctly used in engineering exclusively.*

For universities and land grant colleges the buildings, equipment and land used for general university purposes or for chemistry and physics are not included in the summary. In the universities and land grant colleges a part of the university plant other than engineering should be allocated to engineering, perhaps in the proportion that the number of engineering students bears to the whole number. Under the conditions obtaining in the questionnaire, the comparison of figures is distinctly disadvantageous to the universities and land grant colleges. It is also proper to consider appropriations from federal, state or city sources as the income from a potential or effective endowment especially in comparison with other types of institutions having income from actual endowment. For these reasons the second part of Table 1 is an estimate of the probable effective investment represented. The item ''additional value of plant'' is an estimate based on evidence in the questionnaires as to the probable proportionate value of the university plant which might properly be credited to engineering.

The item ''capitalized public appropriations'' represents the sum that would produce the public appropriations at 5 per cent interest. The amounts of these public funds for the various institutions are given in the questionnaires.

The item ''estimated total equivalent investment'' is approximate, but it represents quite closely the actual situation and affords a fairer basis of comparison.

The weighted average investment per engineering student is $4,800 based on the reported values of property used strictly for engineering education only, whereas the ''total estimated effective investment'' raises the amount of investment per engineering student to $7,420.

The resulting values for total investment devoted to engineering education in the United States, based on a total enrollment of 55,000 students, are approximately:

$\frac{55,000}{24,172} \times \$116,301,503 = \$265,000,000$ investment as reported.

$\frac{55,000}{24,172} \times \$186,645,503 = \$415,000,000$ potential investment as estimated.

The first value of $265,000,000 is based on undervaluation and incomplete listing of buildings, grounds and equipment used by engineering students in other related departments and in general educational activities, and is therefore known to be too small.

Data on Actual and Effective Income.—Table 2 shows the data regarding the sources and amount of income for engineering education for forty-six institutions having enrollments of 22,002 engineering students, classified according to the type of institution. The total income shown is $10,681,374, and from this figure the probable total income devoted to engineering education in the United States is approximately

$$\frac{55{,}000}{22{,}002} \times \$10{,}681{,}374 = \$26{,}700{,}000.$$

From Table 3 the interest at 5 per cent on plant (non-income producing investment) for 21,190 engineering students is $2,553,362, showing a probable total interest charge for 55,000 engineering students of

$$\frac{55{,}000}{21{,}190} \times \$2{,}553{,}362 = \$6{,}600{,}000$$

making a probable effective yearly total

cost for 55,000 engineering students = $33,300,000.*

Data on Tuition and Fees.—The information regarding tuition fees is not complete enough to compute the average fees charged in the different institutions. Table 2, however, shows complete information as to actual receipts from tuition and laboratory fees and therefore the average receipts based on the reported number of students gives accurate information as to the actual average fees paid to the institutions. These are seen to vary from a maximum of $275.36 per student to a minimum of $34.23 per student, with a weighted average for 22,002 engineering students of $172.02.

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* Though it would have been desirable to do so, it has not been possible to include an allowance for depreciation of physical plant in these figures. The principal reason for this is that there is no rational, agreed-upon method of computing depreciation of educational plant now available. Another reason is that it was not possible in the present study to obtain figures for the value of plant in sufficient detail to apply percentage allowances for depreciation to the several items comprising physical plant. If an arbitrary allowance of 2 per cent be made for

Table 2 shows the average income received by forty-six institutions with 22,002 engineering students to be $485.47, and Table 3 shows the computed average cost per engineering student exclusive of interest charges to be $486.38. These results were obtained from separate and distinct data, and as the income and expenditure ought to balance they afford a very close check.

Itemized Average Cost per Student.—Table 3 shows the average costs per engineering student for the different classes of institutions, also the weighted average cost for forty-two institutions with 20,594 engineering students, excluding interest on plant, as $486.38; and for forty-five institutions with 20,594 engineering students, including interest on plant, the average cost is $610.36.

From data given in these tables, the total average cost of educating one engineering student for one year is made up as follows:

Paid by one student	$172
Interest on plant	123
Endowment	124
Public appropriations	142
Other sources	49
	$610 *

The student pays 28.2 per cent of the cost; or, stated in another way, the results for about 22,000 students show that

depreciation of buildings and equipment (investment in buildings constituting nearly three-fourths of the total), approximately $2,000,000 would be added to the total cost of engineering education in the United States—the total cost would then be approximately $35,300,000. Similarly the cost per engineering student per year would be increased from $610 to $646.

about 28.2 per cent of the total expenditures comes from student fees.

Nominal Cost per Graduate.—It is of interest to divide the total cost for undergraduate instruction in one year by the number of men given first degrees in that year. This quotient has been called the "nominal cost per graduate" in Table 3, as it is not intended to imply that graduates are the only legitimate product of an engineering college, or that all expenditures are made in their behalf. Men who fail to graduate pay fees in proportion to the time of their attendance and doubtless profit from their partial courses.

It is shown in Table 3 that the nominal cost per graduate in forty-two institutions is $3,394, excluding interest, and $4,251 with interest included. It is shown in the preceding section that the average student pays $172 per year in fees and that this sum represents 28.2 per cent of the average total cost per student, including interest. A student who is graduated pays a total of $688 in four years, or 16.2 per cent of the nominal cost per graduate. The difference between the 28.2 per cent and the 16.2 per cent, or 12 per cent, is the part of the nominal cost per graduate covered by the fees paid by the non-graduates.

Summary Tables and Diagrams.—Plates I, II, and III, and Tables 1, 2, and 3 are self-explanatory and may be found on the following pages.

1. INVESTMENT DEVOTED TO ENGINEERING EDUCATION AS REPORTED AND THE ESTIMATED TOTAL EFFECTIVE INVESTMENT.

Number of Institutions.	Types of Institutions.	Number of Students.	Investment as Reported in Dollars.					Investment per Engineering Student as Reported.	Probable Effective Investment.			Total Estimated Effective Investment per Engineering Student.
			Endowment.	Buildings.	Equipment.	Land.	Total.		Additional Value of Plant.	Capitalized Public Appropriations 5%.	Estimated Total Equivalent Investment.	
9	Endowed Polytechnic Institutes	7,000	$48,027,278	$15,007,051	$4,418,334	$7,891,493	$75,345,156	$10,760	$......	$ 440,000	$ 75,785,156	$10,800
10	Endowed Universities	3,479	11,205,254	6,128,359	1,848,139	886,088	20,067,840	5,760	8,000,000	3,580,900	31,647,840	9,100
10	State Universities	6,235	1,627,367	5,199,757	1,848,275	432,490	9,107,889	1,460	5,200,000	15,000,000	29,307,889	4,650
3	Schools of Mines	1,014	330,000	1,653,059	1,085,190	229,819	3,298,068	3,250	......	12,324,000	15,622,068	15,400
7	Land Grant Colleges	2,620	224,901	1,689,662	796,370	146,000	2,856,933	1,080	2,500,000	12,600,000	17,956,933	6,850
6	Miscellaneous Institutions	3,824	484,901	2,702,575	1,879,976	558,165	5,625,617	1,470	2,200,000	8,500,000	16,325,617	4,260
45	Institutions	24,172	$61,899,701	$32,380,463	$11,876,284	$10,144,055	$116,301,503	$4,800 Weighted Average.	$17,900,000	$52,444,000	$186,645,503	$7,720 Weighted Average.

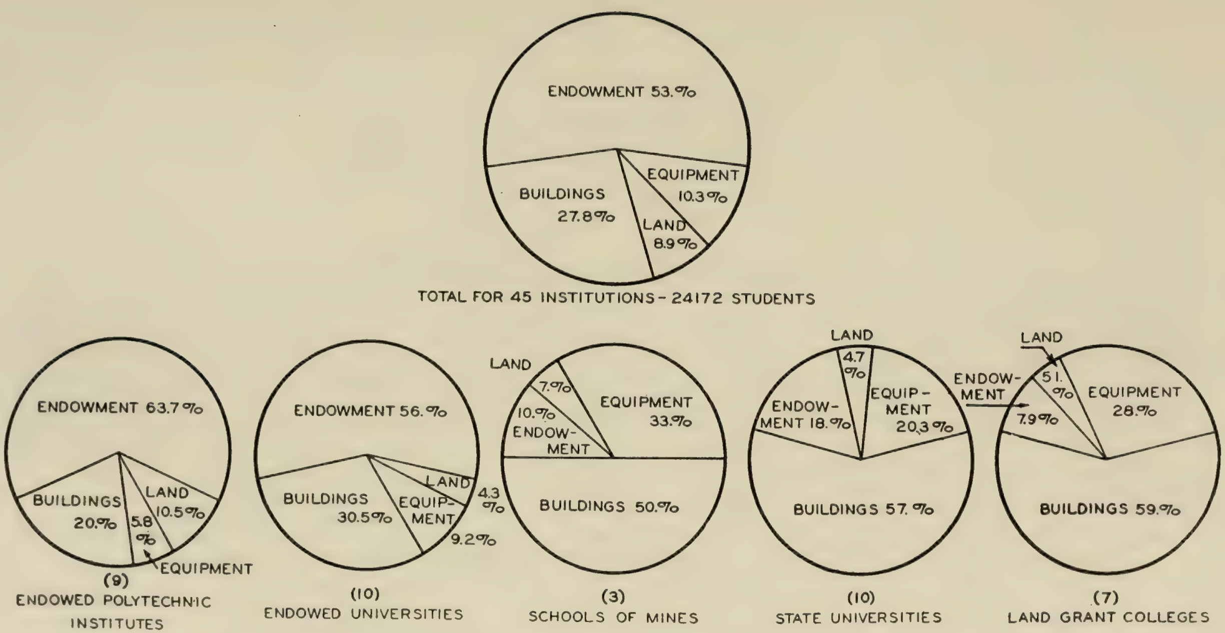


PLATE I. Distribution of Investment Devoted to Engineering Education.

2. SOURCES AND AMOUNT OF INCOME FOR ENGINEERING EDUCATION IN SIX TYPES OF INSTITUTIONS.

	No. of Institutions.	No. of Students.	Income from Fees.	Income from Endowment.	Income from Public Appropriations.	Income from Other Sources.	Total Income.	Average Fee Paid by Each Eng'g Student per Year.
Endowed Poly. Inst.	9	7,000	$1,927,495	$2,038,928	$ 23,000	$486,694	$4,476,117	$275.36
Endowed Univ.....	10	3,479	879,617	583,334	200,946	67,193	1,731,090	252.84
State Univ.........	10	4,505	259,585	25,650	1,118,905	74,404	1,478,544	50.96
Land Grant Col....	7	2,620	89,679	12,734	629,736	5,354	737,503	34.23
Schools of Mines...	4	1,237	83,284	20,682	875,118	181,224	1,160,308	67.32
Misc. Inst.........	6	3,161	545,218	25,595	264,582	262,417	1,097,812	172.48
Total for 46 Instit. .		22,002	$3,784,878	$2,706,923	$3,112,287	$1,077,286	$10,681,374	$172.02 Weighted Average.

$$\frac{10{,}681{,}374}{22{,}002} = \$485.47 = \text{Average Income per Student per Year.}$$

From Table 3 $486.38 = Average Cost per Student per Year.

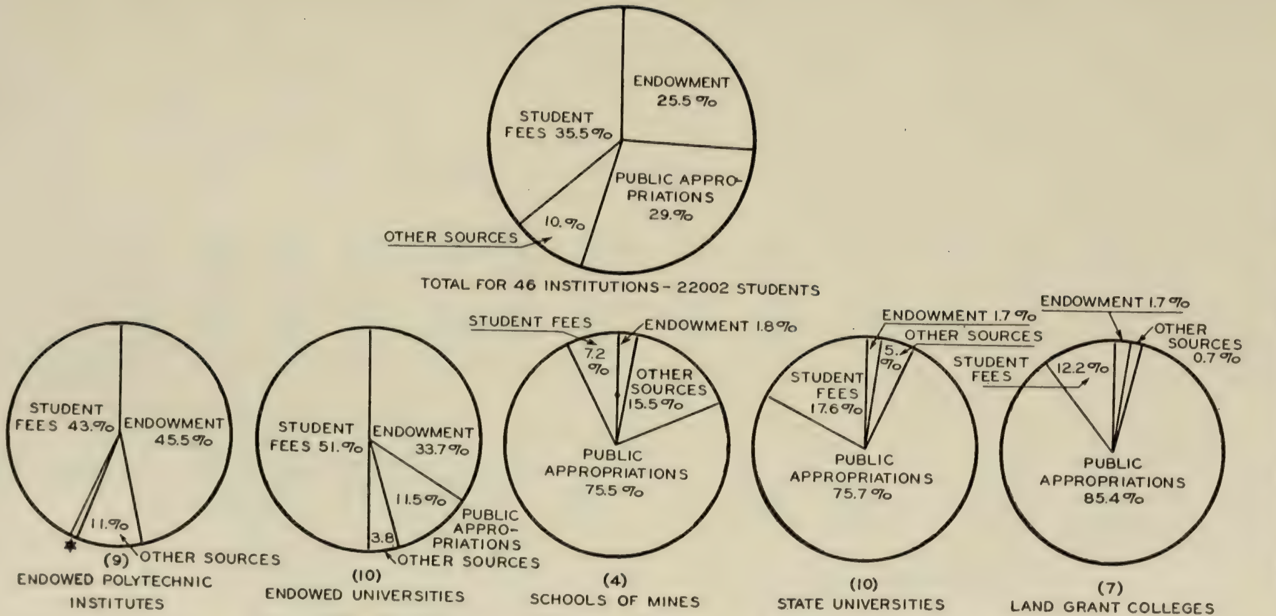
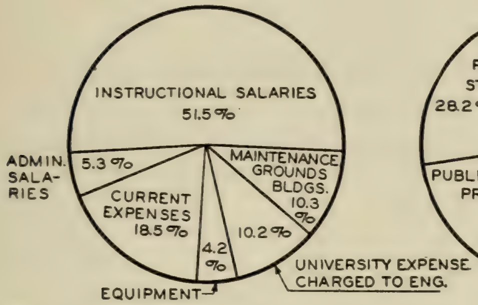


PLATE II. Distribution of Income Devoted to Engineering Education.

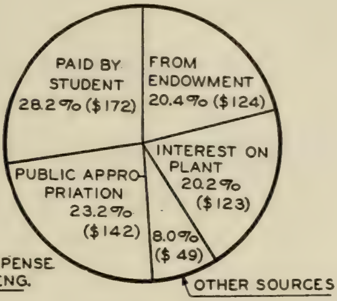
* State Scholarships and Federal Appropriations ½ of 1 per cent.

3. Expenditures for Engineering Education and Costs per Student per Year.

Number of Institutions.	Class or Type of Institution.	Number of Students.	Number Receiv'g First Degree June, 1925.	Instructional Salaries.	Administration Salaries.	Current. Expenses.	Equipment, New and Replaced.	Building and Grounds Maintenance.	University Expense Charged to Engineering.	Total Expense Excluding Interest on Plant.	Interest on Plant.	Total Expense Including Interest on Plant.	Cost per Student per Year Excl. Interest on Plant.	Cost per Student per Year Incl. Interest on Plant.	Nominal Cost per Graduate Excl. Interest on Plant.	Nominal Cost per Graduate Incl. Interest on Plant.
9	Endowed Polytechnic Institutes....	7,000	1,185	$2,062,041	$216,910	$1,058,527	$116,713	$540,152	$......	$3,994,343	$1,252,834	$5,247,177	$570.62	$749.60	$3,390	$4,420
10	Endowed Universities............	3,479	502	1,116,348	129,293	263,182	76,911	215,545	222,280	2,023,559	557,299	2,580,858	581.65	741.83	4,020	5,140
8	State Universities .	3,332	422	584,051	35,809	130,391	75,578	121,820	381,990	1,329,639	248,044	1,577,683	399.05	473.49	3,160	3,740
2	State Universities .	373	40	59,000	4,650	10,895	6,697	14,798	52,349	148,389	......	......	397.83	......	3,700	......
7	Land Grant Colleges...........	2,620	362	489,818	24,850	89,831	30,016	45,022	327,736	1,007,273	137,601	1,144,874	384.45	436.94	2,790	3,180
3	Schools of Mines ..	1,014	131	313,700	40,102	171,791	38,183	23,791	12,426	599,993	148,404	748,397	591.71	738.06	4,580	5,700
1	School of Mines...	223	38	59,205	11.633	45,924	12,095	6,756	1,527	137,140	......	......	614.98	......	3,610	......
5	Misc. Institutions .	3,149	355	612,355	80,843	149,384	72,588	93,588	52,982	1,061,740	209,180	1,270,920	337.12	403.59	3,000	3,590
45 Institutions..........		21,190	3,035	$5,296,518	$544,090	$1,919,925	$428,781	$1,061,472	$1,051,290	$10,302,076			$486.13		$3,394	
42 Institutions..........		20,594	2,957							$10,016,547	$2,553,362	$12,569,909	$486.38	$610.36	$3,394	$4,251



Distribution of Expenditures for Engineering Education.
Total for 45 Institutions—21,190 Students.



Sources from which Funds to Meet Cost per Engineering Student per Year are Obtained.
Cost Including Interest on Plant $610, Excluding Interest $487.

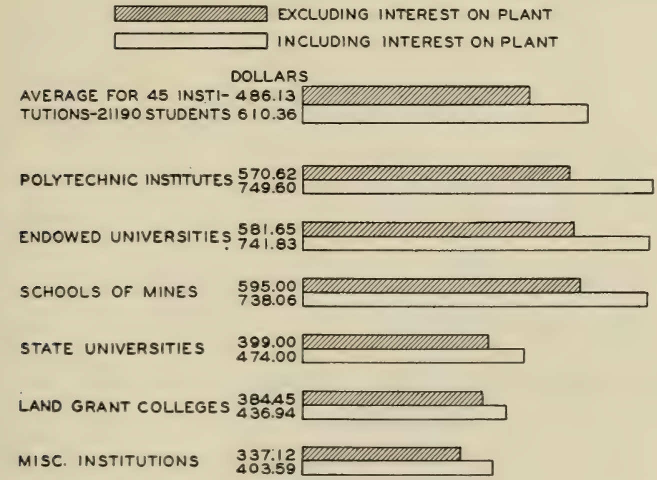


Plate III.

Unit Costs in Engineering Education per Student per Year in Dollars.

BULLETIN NUMBER 7
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF ENGINEERING DEGREES

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ENGINEERING DEGREES

Purpose and Auspices.—The purpose of this study was to summarize past and present practices in conferring engineering degrees and to cite recommendations in the matter which have been presented to the Society in the past. Little attempt has been made to draw conclusions from the facts collected and no new recommendations are presented, the purpose being merely to present the facts of the situation.

The study of degree practices has been made by the Staff, as named elsewhere, with valuable assistance from committees of the faculties of the Missouri School of Mines and Metallurgy and of Lehigh University.

Sources of Information.—Tabulations of present practices have been compiled from catalogues of 150 institutions in the United States which offer engineering curricula. Catalogue statements have been verified by correspondence in all cases where there was doubt as to the exact meaning. It is therefore believed that the tabulations of present practices are both inclusive and accurate. Information regarding past practices has been taken from the Society's *Proceedings* for the years 1895, 1906 and 1910. It is apparent that these tabulations do not include all institutions which conferred degrees in engineering at the time the older summaries were made. The tabulation of 1895, for example, includes but fifty-nine institutions. It is possible that complete tabulations for the earlier years would change the relative proportions of institutions conferring the various degrees somewhat, but it is probable that the general tendencies are shown fairly accurately, since the lists include a good representation of different kinds of institutions and different sections of the country. The recommendations regarding degree practices which are quoted were presented to the Society by a special committee and will be found in *Proceedings* for the year 1918.

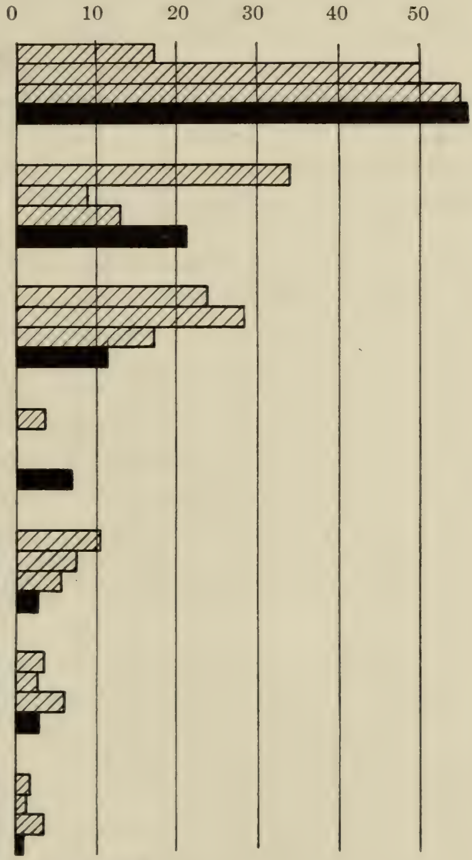
Titles and Abbreviations.—It will be noted that the tabulations list the various degrees as "B.S. in C.E.," "B.C.E.," "C. E.," etc. This was done in preference to using the more general designations applying to all courses, such as "Bachelor of Science with Designation," in order to use the specific titles and to make possible the inclusion of minor modifications of the manner in which the designations are stated. When the degree is entered as "B.S. in C.E." it should, therefore, be understood to include all similar degrees, such as B.S. in M.E., B.S. in E.E., B.S. in E.M., etc. Institutions which do not offer civil engineering curricula have been included in the tabulations and their degrees listed with the corresponding civil engineering degrees. A few institutions offer different undergraduate programs leading to different types of degrees. One college, for example, offers one program leading to the degree Bachelor of Science in Civil Engineering and another program of the same duration, but somewhat different content, leading to the degree Civil Engineer. Another college once offered the degree Civil Engineer in one curriculum and the degree Bachelor of Mechanical Engineering in another curriculum. In such cases both (or all) of the degrees offered as first degrees have been included. The tabulations therefore show a greater number of degree practices than of institutions. Second or post-graduate degrees have been treated separately.

FIRST DEGREES

Past and Present Practices.—Table 1 shows practices relating to first degrees in engineering which have been in effect at four different periods in the past thirty years. Variations in length or type of curricula have not been included but only variations in the several degrees themselves. The lengths of the horizontal bars indicate graphically the proportions of institutions conferring the various degreees. In tabulating the data it was necessary to group together a number of minor modifications of designations, such as "B.S. in C.E.," "B.S. for C.E.," and the like, since the older tabulations were prepared in that manner. The entire range of diversity of practice, therefore, is not shown.

TABLE 1.

Past and Present Practices Relating to First Degrees in Engineering.



		Per Cent	Number
B.S. in C.E., etc.	1895	17.0	10
	1904	50.0	41
	1910	55.2	52
	1925	56.0	84
B.S.	1895	33.9	20
	1904	8.5	7
	1910	12.8	12
	1925	21.3	32
C.E., etc.	1895	23.8	14
	1904	28.0	23
	1910	17.1	16
	1925	11.7	17
B.S. in Eng.	1895	3.3	2
	1904		
	1910		
	1925	6.6	10
B.C.E., etc.	1895	10.2	6
	1904	7.3	6
	1910	5.3	5
	1925	2.7	4
B. Eng.	1895	3.3	2
	1904	2.4	2
	1910	5.3	5
	1925	2.7	4
B.A.	1895	1.7	1
	1904	1.2	1
	1910	3.2	3
	1925	0.7	1

Others.	1895 & 1910	B.Ap.Sc.	2
	1895 & 1904	B.E. in C.E., etc.	2
	1895 & 1904	B.Ph.	2
	1895	B.Ap.Sc. in C.E., etc.	1
	1895	Diploma in C.E., etc.	1
	1925	B.S. in Arts. Eng.	1
	1925	B.Tech.	1
	1925	B.A. in Eng.	1
	1925	B.E. in C.E.	1

Note: Certain of the institutions follow more than one practice in conferring first degrees.

Present Trends.—It is clear, however, that there is considerable diversity of practice in conferring first degrees. No fewer than nine distinctly different degrees conferred at present are included in the list. In some cases differences in practice may be based upon differences in the nature of the curriculum. An institution which offers curricula in civil, mechanical, electrical and chemical engineering, for example, with little differentiation between them, may feel that the degree Bachelor of Engineering, or Bachelor of Science in Engineering is more appropriate than the degree Bachelor of Science with designation of the course. In the great majority of cases, however, the several types of degrees are conferred in curricula which are essentially similar and which might properly lead to the same degree.

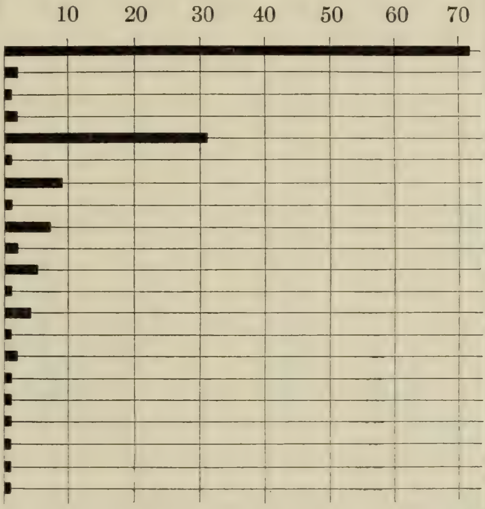
The order in which the several degrees appear in Table 1 is the same as that of the numbers of institutions which confer them at present. It will be noted that somewhat more than half confer the degree Bachelor of Science in Civil Engineering. Next in order comes Bachelor of Science without designation of curriculum, followed by Civil Engineer, Bachelor of Science in Engineering, Bachelor of Civil Engineering, Bachelor of Engineering and others. The degree Bachelor of Technology is new with the present year as far as can be learned.

There is quite general agreement among the institutions upon the propriety of conferring the bachelor's degree rather than the degree of engineer upon completion of an undergraduate curriculum and a majority evidently prefer the particular designation Bachelor of Science in Civil Engineering. This practice is in accordance with the action of the Society in 1910 to which reference will be made later.

It is interesting to trace the course of practice and to read the discussions in the Society's *Proceedings* relative to conferring the degree of engineer as a first degree. Of the fourteen institutions which are listed in the tabulation of 1895 as following this practice, but five have continued it to the present time. The others of the original group now give the

TABLE 2.

FIRST DEGREES AND GRADUATION REQUIREMENTS IN CIVIL ENGINEERING IN 1925.

	Degree	Number of Years Required	Number of Institutions Offering Each Degree	Number	Per Cent of Total Institutions
(a)	B.S. in C.E.	4		72	48.0
(b)	B.S. in C.E.	4c*		2	1.3
	B.S. in C.E.	5		1	0.7
(c)	B.S. in C.E.	5c		2	1.3
	B.S.	4		31	20.6
	B.S.	5		1	0.7
	B.S. in Eng.	4		9	6.0
	B.S. in Eng.	5		1	0.7
	C.E.	4		7	4.5
(d)	C.E.	5		2	1.3
	C.E.	5c		5	3.3
(e)	C.E.	6		1	0.7
(f)	B.E.	4		4	2.7
	B.E. in C.E.	4		1	0.7
	B.C.E.	4		2	1.3
	B.C.E.	4c		1	0.7
	B.C.E.	5c		1	0.7
	B.A.	4		1	0.7
	B.A. in Eng.	4		1	0.7
	B.S. in Arts.E.	4		1	0.7
	B. of Tech.	4		1	0.7
	Institutions conferring degrees in engineering			150‡	100
	Institutions offering the civil engineering course			138†	92.0
	Institutions which offer no civil engineering course			12	8.0

---

* "c" Denotes cooperative course.

‡ Nine institutions follow more than one practice in conferring degrees for the civil engineering course.

† As of 1924–1925.

(a) Three institutions designate this degree S.B. in C.E. One institution designates this degree B.Sc. in C.E.

(b) One institution requires 4 years of 12 months each.

(c) One institution requires 5 years of 11½ months each.

(d) B.S. in Engineering may be obtained at the end of eighth term.

(e) Beginning 1926, this institution will offer a 5-year course leading to the degree of B.S. One institution requires 3 years of 4 quarters. One institution requires 96 weeks for the entire course.

(f) One institution requires 6 months of summer engineering practice.

bachelor's degree in one form or another. It is understood that one other of the original group has taken steps to change its practice in the immediate future. There have, however, been additions to the list since 1895 and there are now seventeen institutions which confer the degree of engineer as a first degree. Of the seventeen, five offer cooperative courses of five or more years' duration; three confer the degree upon completion of full-time residence courses of five or more years' duration; one has changed from the degree Bachelor of Science in Engineering to the degree Civil Engineer; one did not offer engineering curricula in 1895; and two, though not included in the 1895 tabulation, probably conferred the degree of engineer at that time. It may be worth noting that 1,307 degrees of Civil Engineer, Mechanical Engineer, and the like were included in the 8,569 first degrees in engineering conferred by the 150 colleges in 1925.

Diversity of Present Practices.—Table 2 has been included to indicate the diversity of practice in awarding first degrees in engineering, both as to designation of the degree and as to the duration and types of curricula. Civil engineering curricula only are included. It will be noted that there are no fewer than twenty-one different variations of practices or requirements. The table is not intended in any sense as a criticism of the diversity of types of programs but merely to indicate the fact that many different degrees are conferred upon satisfaction of essentially similar requirements. This is shown quite clearly in the case of the cooperative courses since five different degree practices are in effect in the twelve institutions which offer cooperative curricula in civil engineering.

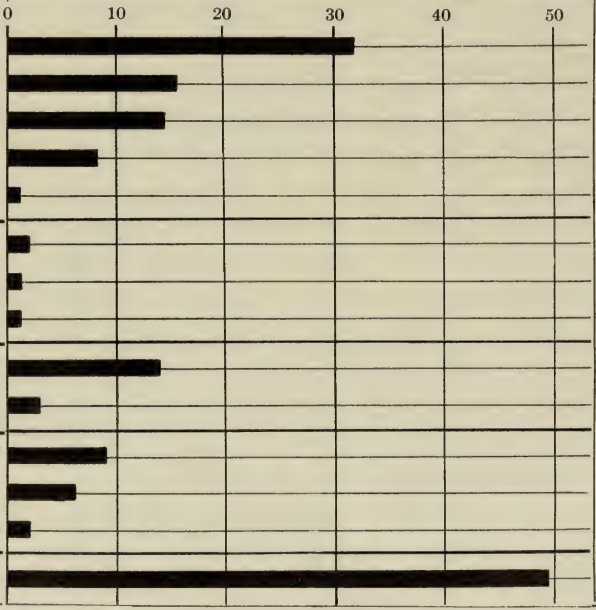
THE DEGREE OF ENGINEER

Existing Confusion.—The diversity of practice in conferring the degree of engineer is even greater than in conferring first degrees. In fact there seems to be no agreement as to the *principles* upon which such degrees should be granted. Table 3 is a summary of present practices. It will be noted that forty-nine institutions have no published provisions

TABLE 3.

REQUIREMENTS FOR THE DEGREE OF ENGINEER IN 1925.

Number of Institutions Specifying Each Requirement



Requirements		Num-ber	Per Cent of Institu-tions
Practice in Absentia	3 Years Practice	31	20.3
	5 Years Practice	15	10.0
	4 Years Practice	14	9.3
	2 Years Practice	8	5.3
	7 Years Practice	1	0.6
Post-graduate Study in Residence plus Practice	1 Yr. in Residence plus 1 Yr. Practice	2	1.3
	1 Yr. in Residence plus 2 Yrs. Practice	1	0.6
	1 Yr. in Residence plus 4 Yrs. Practice	1	0.6
Post-graduate Study in Residence	1 Year Post-graduate Study	14	9.3
	2 Years Post-graduate Study	3	2.0
Undergraduate Study	4 Years Under-graduate Study	9	6.0
	5 Years Cooperative	6	4.0
	5 or 6 Years in Residence	2	1.3
No published Provision		49	32.6

Note: Many institutions do not definitely state requirements for thesis. Of the 150 institutions included 6 have optional requirements.

whatever; that sixty-nine confer the degree upon the basis of practical experience, with or without requirement of a thesis; four upon the basis of both post-graduate study in residence and practical experience; seventeen upon the basis of post-graduate study in residence only; and seventeen upon the basis of undergraduate curricula only. Of the one hundred and one institutions which have published provisions for the award of the degree of engineer, seventy-three, or approximately three-quarters, evidently believe that demonstrated inclination and fitness to follow engineering as a vocation after graduation constitute a necessary part of the requirement. This point has been frequently stressed in the discussions at the Society's meetings.

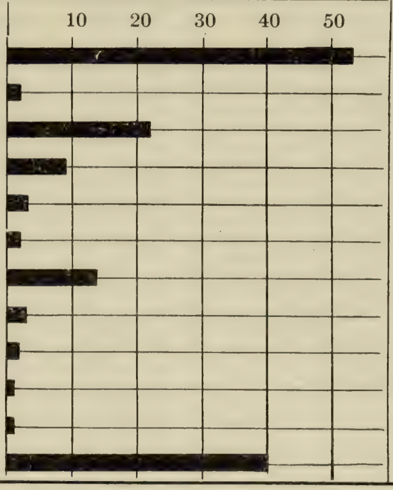
Propriety of the Degrees.—It is apparent that a considerable number of colleges believe that academic institutions should confer degrees for work in course only. It may be this belief, possibly coupled with the feeling that an engineer can not be qualified for the responsible practice of his profession by a college course alone, which has deterred so many institutions from making any provision whatever for conferring the degree of engineer. A majority of the institutions, however, seem to believe that the title Civil Engineer has a legitimate place among professional men and that it is the function of the colleges to confer it. As above stated, however, there seems to be no agreement either as to the principles or the specific requirements upon which professional degrees should be conferred.

ADVANCED DEGREES IN COURSE

Summary of Present Practices.—Table 4 shows the present practices of the colleges in conferring advanced degrees in engineering for work in course. It will be noted that forty institutions make no provision for post-graduate engineering curricula. Of the one hundred and ten which do, one-half confer the degree Master of Science without designation of curriculum. The remaining half confer either Master of Science with designation of curriculum or the degree of

TABLE 4.

SECOND DEGREES IN ENGINEERING AND REQUIREMENTS THEREFOR IN 1925.

Degrees and Requirements		Institutions Specifying Each Degree or Requirement	Number	Per Cent of Institutions
M.S.	—1 Yr. in Residence		53	35.4
M.S.	—2 Yrs. in Residence		2	1.3
M.S. in C.E.	—1 Yr. in Residence		22	14.7
M.S. in Eng.	—1 Yr. in Residence		9	6.0
M.C.E.	—1 Yr. in Residence		3	2.0
M.C.E.	—2 Yrs. in Residence		2	1.3
C.E.	—1 Yr. in Residence		14	9.3
C.E.	—2 Yrs. in Residence		3	0.7
C.E.	—1 Yr. in Res. + 1 Yr. Practice		2	2.0
C.E.	—1 Yr. in Res. + 2 Yrs. Practice		1	1.3
C.E.	—1 Yr. in Res. + 4 Yrs. Practice		1	0.7
No Provision			40	26.7

engineer. Four institutions confer the degree of engineer on a basis of post-graduate study in residence plus practical experience. The diversity of practice in conferring advanced degrees is quite as great as in conferring first degrees.

RECOMMENDATIONS RELATING TO DEGREES

Report of 1910.—The most concrete recommendation to the Society in the matter of degrees was presented by a special committee at the annual meeting of 1910. This was based upon an analysis of the then existing situation and presented explicit recommendations as to the basis upon which the several degrees should be conferred. The complete report of the committee will be found on pages 135 et seq. of Vol. XVIII of the Society's *Proceedings.* The principal recommendations with reference to first degrees, advanced degrees, and professional degrees are repeated here to indicate the extent of agreement of past and present practices with them.

> "I. A four-year engineering course should normally lead to the degree Bachelor of Science (B.S.), to which should be added a specifying phrase, as for example, Bachelor of Science in Civil Engineering."
>
> "IV. One year of resident work in graduate engineering and scientific subjects by a Bachelor of Science in Engineering should normally lead to the degree Master of Science (M.S.) with the specifying phrase, as, for example, Master of Science in Civil Engineering."
>
> "VI. The professional engineering degrees, C.E., M.E., etc., should be given only to graduates who present satisfactory evidence of professional work of superior quality extending over not less than three years, and who submit a satisfactory thesis."

Conclusion.—It will be noted from a study of the preceding tabulations that more of the colleges adhere to recommendations I and VI than to any other one practice; in fact this was the case at the time the report was presented. Only a minority, however, follow recommendation IV. Since the submission of the report there has been some tendency toward the adoption of its recommendations though there is still far from that uniformity which the committee (and apparently the Society membership) evidently believed to be desirable.

In general, the foregoing summary of degree practices in engineering seems to warrant the conclusion that the present situation is not a satisfactory one, particularly when compared with that in other major professions.

BULLETIN NUMBER 8
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF A GROUP OF ELECTRICAL ENGINEERING GRADUATES

Conducted under the Auspices of the
Eta Kappa Nu Association

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A STUDY OF A GROUP OF ELECTRICAL ENGINEERING GRADUATES

Purposes and Auspices.—This bulletin summarizes the results of an inquiry concerning the occupations, earnings and views on engineering education of the alumni members of Eta Kappa Nu, an honorary fraternity of electrical engineering students and graduates.

The more extended study of graduates of all engineering courses, which is set forth in Bulletin No. 3 of this series, dealt with a large and rather heterogeneous group of individuals representing all occupations and fields of activity in which engineering graduates are to be found. To serve as a check upon the results of such a study it was thought advisable to conduct an inquiry among a reasonably homogeneous group not likely to view matters relating to engineering education from too widely divergent standpoints of training, experience and interest.

The alumni members of Eta Kappa Nu seemed to fit these requirements admirably. The members of the fraternity are selected from a single curriculum. Its chapters are located in institutions of high standing. Qualifications for membership include not only superior attainment in scholarship but also personal qualities which give promise of success after graduation. Most of the alumni members are graduates of fairly recent classes who are thus acquainted with engineering courses as conducted at present. An invitation to participate in the study was therefore extended to the fraternity and was cordially accepted.

The questionnaire upon which the results of the study are based was circulated to 1,714 individuals, 844 of whom responded; a return of approximately fifty per cent. Data relating to earnings have been taken from the results of an independent study conducted by the fraternity in 1923.* In that study 1,118 replies were received from among 1,770 individuals canvassed, a return of approximately sixty-three per cent. These large percentages of returns probably furnish a representative sampling of the entire alumni membership of the fraternity.

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* See *The Bridge of Eta Kappa Nu* for November, 1923, January, 1924, and May, 1924.

An analysis of the results of the study follows.

PART I. OCCUPATIONS AND EARNINGS

Distribution in Various Kinds of Activity.—The kinds of positions and fields of activity of graduates are factors to be considered in many of the problems of engineering education. In the past, accurate knowledge in this regard has been meager. Guesses and opinions have too often been advanced as facts. A statement which is often heard, for example, is that over half of all engineering graduates leave engineering work for other fields. The results of the present study indicate quite the contrary. The distribution of graduates among the several functional types of activity (research, design, supervision, management, commercial, etc.) is of special importance. The data which are summarized in the following tables and diagrams give an unusually clear picture of this situation in the field of electrical engineering.

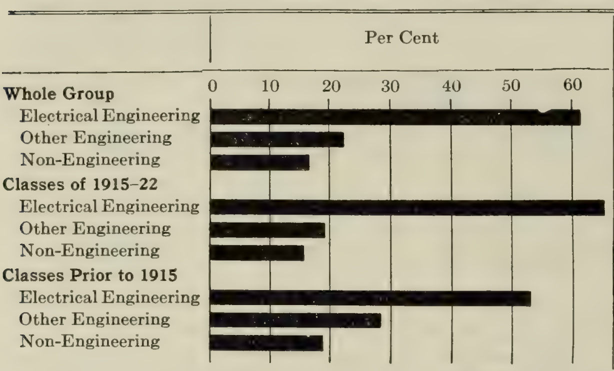
It is apparent from Table 1 that big industry, in the field of electrical engineering at least, absorbs a large proportion of the engineering graduates of the country since more than half of the alumni members of Eta Kappa Nu are employed by large industrial concerns or public utilities. It also appears that a larger proportion of electrical engineering graduates are employed in electrical manufacturing than in any other principal division of the field. It should be remembered in examining the figures that a considerable proportion of the miscellaneous group have left the field of electrical engineering and are employed in other lines of work. It is therefore probable that more than one-half of those who do remain in electrical engineering work are connected with manufacturing concerns.

TABLE 1

BUSINESS CONNECTIONS OF ETA KAPPA NU ALUMNI

	No.	Per Cent	Totals Per Cent
Power Production and Transportation			
Large central stations	140	13.0	
Small central stations	24	2.2	
Electric railways	17	1.6	16.9
Communications			
Telephone operating companies	155	14.4	
Telephone manufacturing companies	68	6.3	20.8
Electrical Machinery Manufacturing			
Large electrical manufacturing companies	191	17.8	
Medium size electrical manufacturing companies	55	5.1	
Small electrical manufacturing companies	15	1.4	24.3
Miscellaneous Manufacturing	121	11.3	11.3
Contracting	37	3.4	3.4
Miscellaneous			
Teaching	53	4.9	
Government employ	26	2.4	
Jobbers	17	1.6	
Unclassified	154	14.3	23.3
GRAND TOTALS	1,073		100.0
Total in Manufacturing and Contracting	487		45.3
Total in Public Utilities	336		31.3
Total in Miscellaneous Activities	250		23.3

Fig. 1 shows the distribution of Eta Kappa Nu alumni in *electrical engineering, other engineering* and *non-engineering* fields. Of the entire number 61.4 per cent are in the same field as their college course, 22.1 per cent are in other engineering and 16.5 per cent are in non-engineering activities. These figures differ slightly from those compiled for the graduates of all engineering courses. The Eta Kappa Nu figures show a larger proportion in the same field as their college course (61.4 per cent against 56.7 per cent), about the same proportion in other engineering work and a smaller proportion in non-engineering work. It is interesting to note that the members of the older classes show a smaller percentage



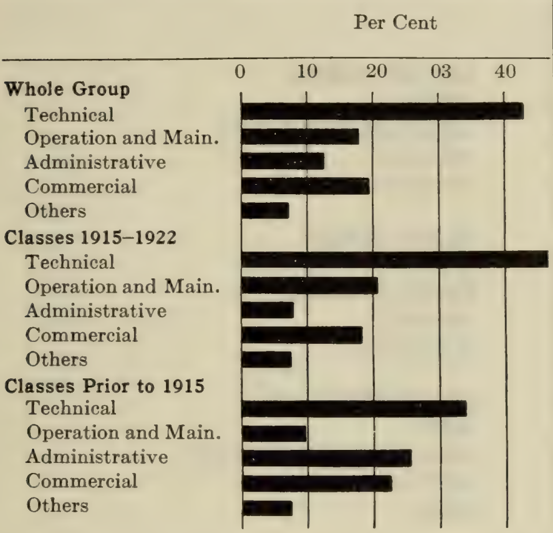
	Number	Per Cent
Whole Group		
Electrical Engineering	518	61.4
Other Engineering	187	22.1
Non-Engineering	139	16.5
Classes of 1915–22	844	100.0
Electrical Engineering	377	65.2
Other Engineering	111	19.2
Non-Engineering	90	15.6
Classes Prior to 1915	578	100.0
Electrical Engineering	141	53.0
Other Engineering	76	28.6
Non-Engineering	49	18.4
	266	100.0

FIG. 1. Occupational distribution of Eta Kappa Nu Alumni.

in electrical engineering. This is to be expected and may be considered a normal and healthy condition.

Figs. 2 to 5 inclusive show the distribution of electrical engineering graduates in various functional activities. The data have been grouped in a few rather than a number of classifications: (1) technical, including such activities as designing, research, testing, and inspection; (2) operation and maintenance; (3) administrative activities, including executive direction, management, and the like; (4) commercial activities, including sales; (5) other activities. These diagrams are worthy of careful study. One feature of the diagrams is especially striking, namely, the relative proportions of the several groups who are engaged in work which is primarily administrative in nature. It should not be assumed in considering this feature of the diagrams that positions of an administrative nature involve greater responsibilities than other types of positions.

Distribution by Functions in Electrical Engineering.—Fig. 2 shows the distribution in five groups of functional activities of Eta Kappa Nu alumni who are engaged in the field of electrical engineering. The first part of the diagram shows the distribution of the entire group, while the second two parts show the distribution of graduates of recent classes and of older classes. It will be noted that 12.7 per cent of the entire group are in administrative work and that 42.9 per cent are in technical work. The diagram shows that a larger proportion of men in the older classes than in the recent classes are in administrative work. This gain in the administrative group is at the expense of the technical and operation and maintenance groups. There is a small increase in the proportion in commercial work.

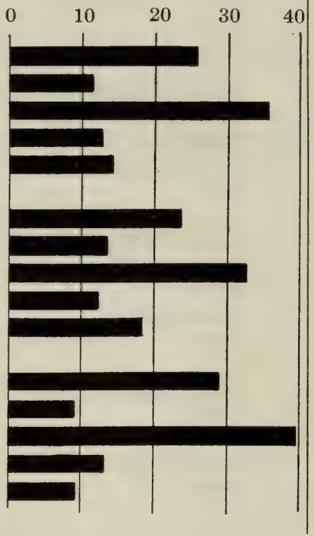


	Number	Per Cent
Whole Group		
Technical	222	42.9
Operation and Main.	92	17.8
Administrative	66	12.7
Commercial	100	19.3
Others	38	7.3
	518	100.0
Classes 1915–1922		
Technical	174	46.1
Operation and Main.	78	20.7
Administrative	30	7.9
Commercial	68	18.1
Others	27	7.2
	377	100.0
Classes Prior to 1915		
Technical	48	34.0
Operation and Main.	14	9.9
Administrative	36	25.6
Commercial	32	22.7
Others	11	7.8
	141	100.0

FIG. 2. Occupational distribution in various functional activities. Electrical engineering group (61.4 per cent of the entire number).

Distribution by Functions in Other Engineering Fields.—Fig. 3 shows the same analysis for men in *other* engineering activities. The same shift from technical and operation and maintenance activities to administrative work is indicated.

The proportion of graduates of recent classes and of older classes in commercial activities is about the same.

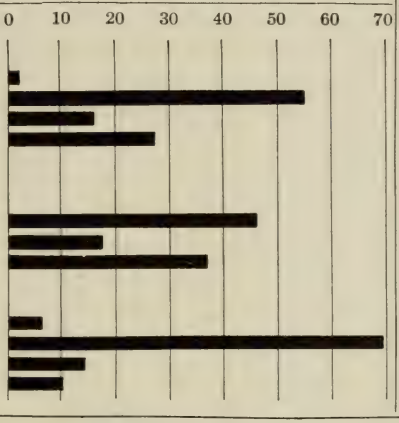


	Number	Per Cent
Whole Group		
Technical	48	25.7
Operation & Maintenance	22	11.8
Administrative	66	35.3
Commercial	24	12.8
Others	27	14.4
Classes of 1915–22	187	100.0
Technical	26	23.4
Operation & Maintenance	15	13.5
Administrative	36	32.4
Commercial	14	12.6
Others	20	18.1
Classes Prior to 1915	111	100.0
Technical	22	29.0
Operation & Maintenance	17	9.2
Administrative	30	39.4
Commercial	10	13.2
Others	7	9.2
	76	100.0

FIG. 3. Occupational distribution in various functional activities. Other engineering group (22.1 per cent of the entire number).

Distribution by Functions in Non-Engineerng Fields.—Fig. 4 shows the same distribution in *non*-engineering activities. As might have been expected none of this group is in technical work and only a small number in operation and maintenance. Over half of the entire group are in work of an administrative or executive nature.

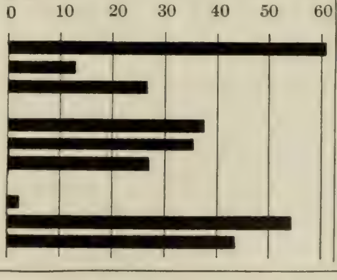
Comparative Distribution by Functions.—Fig. 5 shows a comparison of the distribution of the men in electrical engineering, other engineering, and non-engineering. In order to make the comparison more distinct, operation and maintenance has been grouped with technical work and the proportions in "other" and commercial activities have been grouped together. The comparison of proportions in the technical group and in the administrative and executive group is striking.



	Number	Per Cent
Whole Group		
Technical	0	
Operation and Main.	3	2.2
Administrative	74	54.4
Commercial	22	16.2
Others	37	27.2
Classes 1915–22	136	100.0
Technical	0	
Operation & Main.	0	
Administrative	40	46.0
Commercial	15	17.2
Others	32	36.8
Classes Prior to 1915	87	100.0
Technical	0	
Operation & Main.	3	6.1
Administrative	34	69.4
Commercial	7	14.3
Others	5	10.2
	49	100.0

Fig. 4. Occupational distribution in various functional activities. Non-engineering group.

The fact that technical work of design, research, and the like is entered by a large majority of the graduates and that work of this character is the normal starting place on the road



	Number	Per Cent
Electrical Engineering		
Technical, incl. Opn. & Main.	314	60.7
Administrative	66	12.7
Commercial and Others	138	26.6
Other Engineering	187	100.0
Technical, incl. Opn. & Main.	70	37.5
Administrative	66	35.3
Commercial and Others	61	27.2
Non-Engineering	187	100.0
Technical, incl. Opn. & Main.	3	2.2
Administrative	22	54.4
Commercial and Others	59	43.4
	84	100.0

Fig. 5. Comparative distribution of three groups of men in functional activities.

to promotion to positions of administrative responsibility is clearly indicated. It is to be expected that the proportion of graduates in the non-engineering group who are in administrative work would be greater than the proportions in the other groups. Again, it must not be assumed that positions designated as *administrative* are of greater importance or involve greater responsibilities than those designated as *technical,* in fact the reverse is generally the case with the positions occupied by the younger graduates.

Earnings.—Curves of earnings obtained from the Eta Kappa Nu study of 1923 and from a similar study conducted in 1924 by the Society for the Promotion of Engineering Education are shown by Fig. 6. In the Eta Kappa Nu study, 1,118 men of all classes of twenty years or less experience supplied information. In the S. P. E. E. study 4,907 graduates of the classes of 1924, 1923, 1922, 1919, 1914, 1909 and 1904 supplied information, 1,386 of these being electrical engineering graduates. A few Eta Kappa Nu men probably answered the S. P. E. E. questionnaire as well as that circulated by the fraternity and are thus included in both groups. There is probably not a large enough number of such men, however, seriously to affect the comparison of results.

The middle curve of the S. P.E. E. data is based on median values (the median is the middle number and has as many numbers larger than itself as it has numbers smaller than itself). The middle Eta Kappa Nu curve is based on averages. The general tendency is for averages to exceed medians slightly. The upper S. P. E. E. curve is the lower boundary of the upper 10 per cent of all cases. The lowest S. P. E. E. curve is the upper boundary of the lowest 10 per cent. The Eta Kappa Nu upper and lower curves similarly bound the upper and lower 5 per cent of the cases.

The three curves near the middle of the diagram show a very good agreement. If medians instead of averages had been used in the Eta Kappa Nu data, the agreement would probably have been even closer.

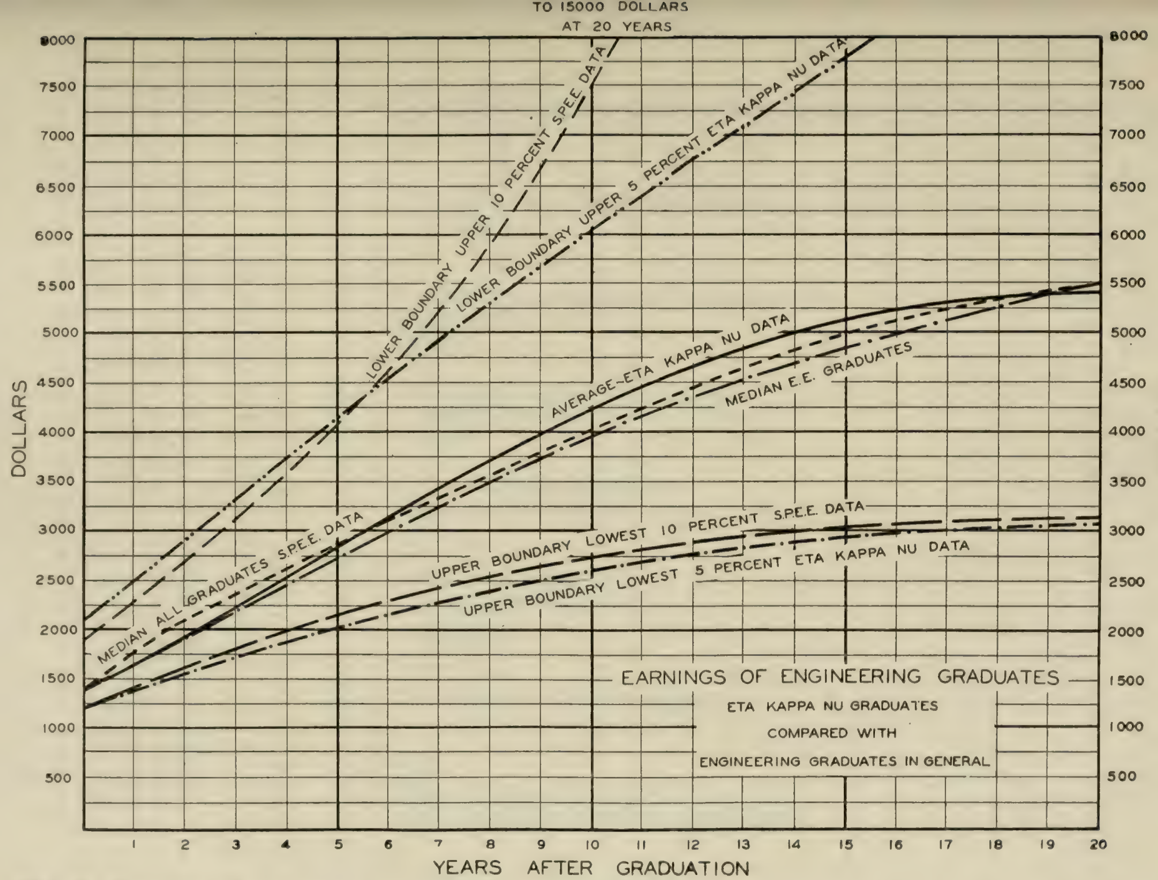


FIG. 6. Earnings of engineering graduates. Data assembled by Eta Kappa Nu and by the Society for the Promotion of Engineering Education.

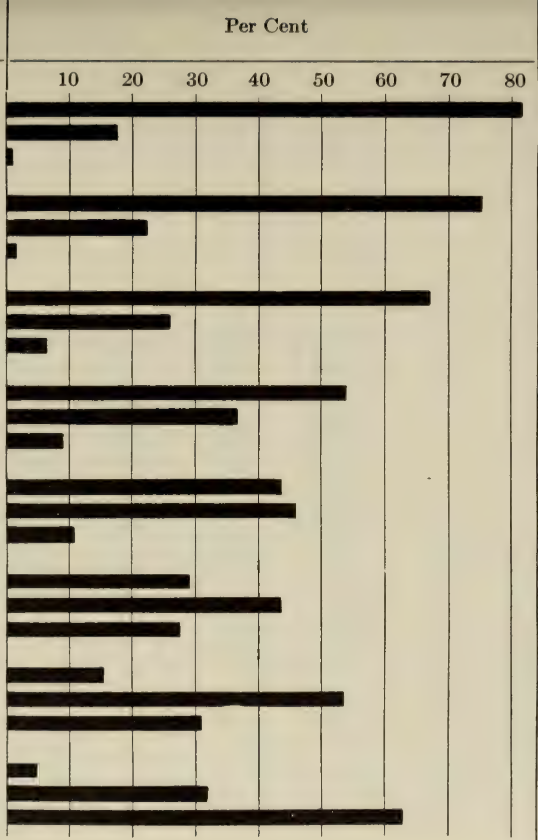
The minimum 10 per cent curve of the S. P. E. E. data is quite close to the minimum 5 per cent curve of the Eta Kappa Nu data, showing twice as large a proportion of graduates in general below the line of small earnings. On the other hand the S. P. E. E. upper 10 per cent curve exceeds the Eta Kappa Nu upper 5 per cent curve. The spread of earnings among the Eta Kappa Nu men is strikingly smaller than that of all graduates. This may be due in part to the fact that such a large proportion of the Eta Kappa Nu alumni are employed by large industrial concerns. It should not be inferred that earnings constitute the only, or even the most important, criterion of success. Earnings are, however, more easily determined than other factors. A more valid indication would be the types of position and degrees of responsibility or some other such measure. It is impossible, however, to define these criteria with sufficient distinctness to reduce them to statistical form. Earnings themselves are, of course, a matter of direct importance and the data herein presented are believed to be of considerable value.

It should be remembered in studying the diagram that a much larger percentage of Eta Kappa Nu members responded than was the case in the S. P. E. E. study. This fact may have some influence on the results. It should also be remembered, however, that Eta Kappa Nu members are a picked group of excellent scholastic standing, whereas the S. P. E. E. study included all graduates, irrespective of standing.

PART II. OPINIONS CONCERNING THE ELECTRICAL ENGINEERING CURRICULUM

Relative Importance of Principal Divisions.—The questionnaire on which these results are based provided for each man to indicate by a check mark whether he assigned *little, moderate* or *great* value to the various items listed. Space was also provided in which those who had not studied some of the subjects could so indicate.

Fig. 7 shows the relative importance which members of Eta Kappa Nu assigned to the different divisions of the curriculum.



	Number	Per Cent
Sciences		
Great	673	81.3
Moderate	148	17.9
Little	7	0.8
English	828	100.0
Great	580	75.5
Moderate	175	22.8
Little	13	1.7
Electrical Engineering Subjects	768	100.0
Great	553	67.2
Moderate	217	26.4
Little	53	6.4
Economics	823	100.0
Great	378	54.1
Moderate	256	36.6
Little	65	9.3
Other Engineering Subjects	699	100.0
Great	337	43.4
Moderate	357	45.9
Little	83	10.7
Shop	777	100.0
Great	233	29.0
Moderate	348	43.4
Little	222	27.6
Cultural Subjects	803	100.0
Great	95	15.4
Moderate	331	53.4
Little	193	31.2
Modern Languages	619	100.0
Great	33	4.8
Moderate	218	32.0
Little	431	63.2
	682	100.0

FIG. 7. Values assigned to various subjects or groups of subjects of the electrical engineering curriculum.

Evidently all believe in the importance of the fundamental sciences since over four-fifths of the replies assigned *great* value to them and only a negligible number assigned *little* value. English follows the science group very closely. Next in order are the electrical engineering courses proper; followed by economics, other engineering, and shop. Modern languages come last, nearly two-thirds of the answers assigning little value to them.

Some interesting differences in the points of view of the men in various lines of activities as to the relative importance of these groups of subjects were brought out by a further analysis of the results not shown by the diagrams. All agree in the fundamental importance of the sciences and English. There is considerably more emphasis on the importance of economics among the other engineering and non-engineering groups than there is among those in electrical engineering. There is also some difference of opinion as to the importance of cultural subjects, the men in electrical engineering holding them to be of somewhat less value than do the men in other groups. As was to be expected, the electrical engineering group attached the greatest importance to the electrical engineering subjects. Similarly, the men in *other* engineering work assign greater importance to the *other* engineering subjects. All agree that shop work is of moderate importance, though the non-engineers assign it less value than do the engineers. All agreed that modern languages are of little value.

The relative importance assigned to the various subjects by men in different functional activities is interesting. There is substantial agreement as to the fundamental importance of English. There is no dissent from the opinion that the sciences are of fundamental importance. All believe that cultural studies are of moderate importance. There is considerable divergence of opinion, however, in the matter of economics and related subjects, as shown by the following tabulation:

	Percentage of Men Giving Replies Indicated. Men in Work Primarily Technical.	Men in Work Primarily Administrative.
Little importance	17.8%	6.4%
Moderate importance	50.5%	23.2%
Great importance	26.7%	70.4%

Men in technical activities assign much greater value to the engineering subjects than do those in administrative activities. Shop is held to be of moderate importance by all.

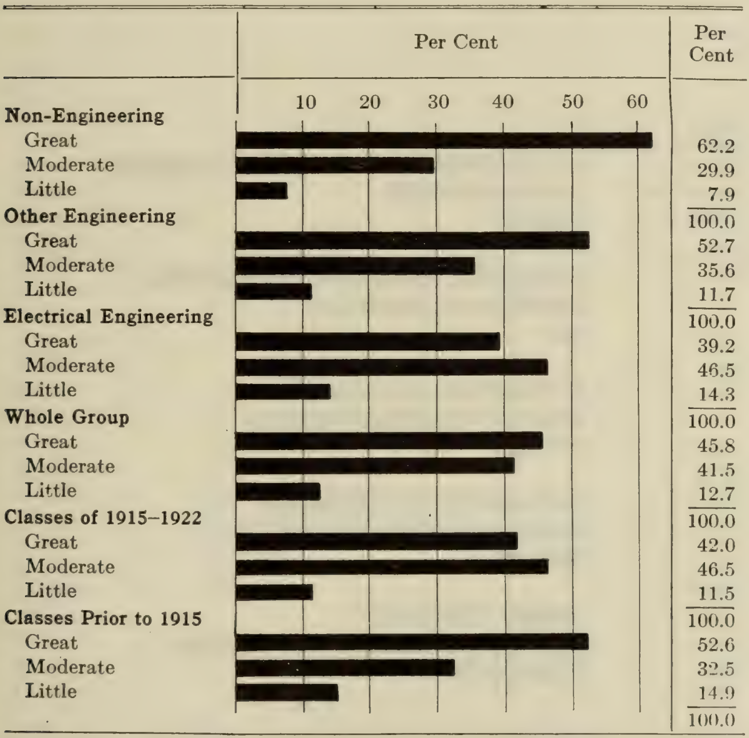


Fig. 8. Need for more training in economics. Classification by groups.

Need for More Training in Economics.—The need for more training in economics in the college curriculum is felt to the following extent: Little—12.7 per cent, moderate—41.5 per cent, great—46.9 per cent, these figures being the percentages of answers of the entire group of Eta Kappa Nu alumni. The older men indicated greater need than did the younger men, and to a well-marked extent. The non-engineering group indicated the need materially more than the others, and graduates who are pursuing strictly electrical engineering work felt the need least. Similarly in the functional classification, the administrative group felt the need considerably more than the technical group. Figs. 8 and 9 present a condensed summary of these results.

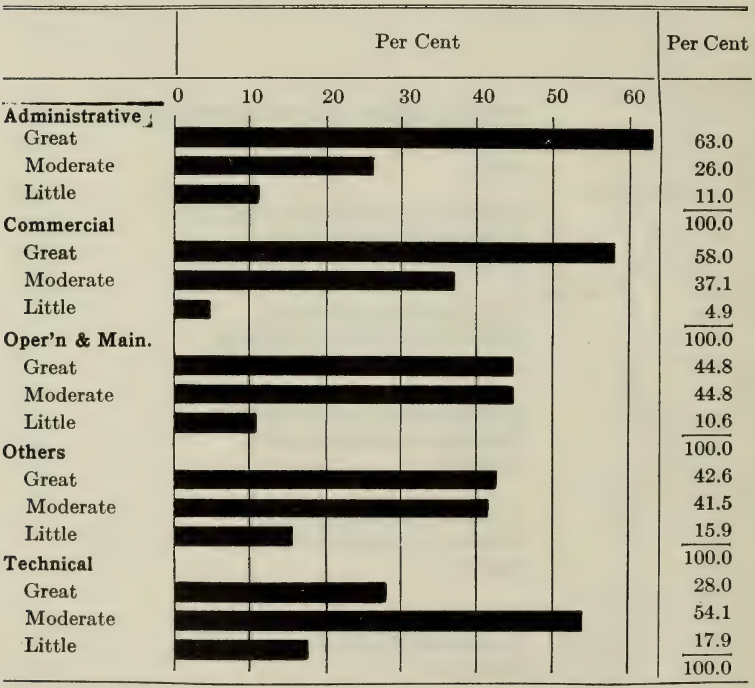


FIG. 9. Need for more training in economics. Classification by functional activities of men replying.

What May be Reduced.—If more work of this character is to be given, it is obvious, in view of present crowding, that other parts of the curriculum must be reduced or the length of the course must be increased. The latter alternative is one which many believe to be undesirable for the majority of engineering students. Without attempting to settle the larger question, opinions have been gathered as to the subjects which might be reduced with the least damage to make way for more extended economic training. The opinions of Eta Kappa Nu members are shown in Fig. 10. The curriculum has been divided into four principal groups of subjects, namely, English, the sciences, technical engineering and cultural subjects. Few believe that there should be any reduction in the sciences or English. The majority would reduce the cultural and engineering subjects. Two hundred and sixteen men did not answer this question and it may be inferred that they felt that no division of the curriculum could be reduced profitably. Apparently it is the belief that the cultural subjects, exclusive of English, should be reduced to a greater extent than the technical engineering subjects. All groups, whether classified technically or functionally, are in close agreement on this matter.

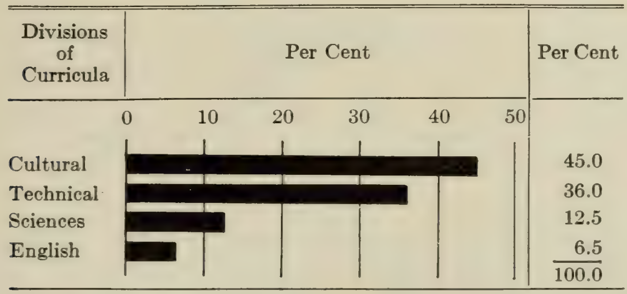


FIG. 10. Divisions of curricula to be revised in favor of additional economic training.

Subjects Considered of Least Value.—In this connection it was desired to obtain spontaneous statements. Hence no list of subjects was given against which check marks could be placed as in previous questions, but each respondent was requested to write the name of a subject or subjects which he considered of least value. Fig. 11 shows a tabulation of the results.

In this list modern foreign languages lead by a considerable margin. These are followed by advanced engineering subjects, higher mathematics and shop, each of which was mentioned about an equal number of times. Only about one-tenth of the replies mentioned cultural subjects and still fewer mentioned other subjects. One hundred and fifty men did not reply at all. Apparently there is only one subject of the engineering curriculum, namely modern foreign languages, upon which any substantial number of graduates agree. In this respect, the results of the Eta Kappa Nu study are in accord with other similar inquiries. The Eta Kappa Nu alumni also agree with graduates in general as to the importance of other subjects, since no subject except foreign languages is mentioned by any considerable number. In fact, many specifically state as their opinion that all subjects of the engineering curriculum are of sufficient value to warrant their retention.

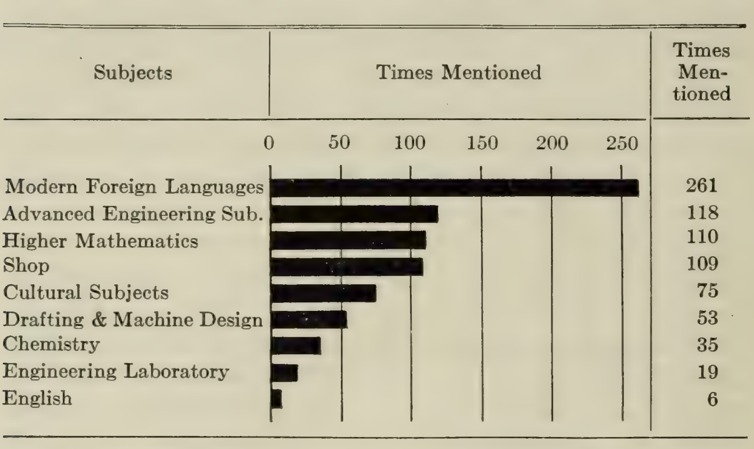


FIG. 11. Subjects of curriculum considered of least value. (No subjects are mentioned in 150 of the replies in a total of 844.)

PART III. STUDY AFTER GRADUATION

How Guided.—The great majority of engineering graduates more or less systematically continue to pursue studies begun in college or undertake study in new lines. One of the greatest opportunities before American engineering colleges today appears to be the advising or directing of graduates in the continuation of their education. Many large industrial firms recognizing the need of further training of engineering graduates have developed systematic post-scholastic courses which graduates enter upon leaving college. Certain of the correspondence schools, particularly those offering general business courses, enroll large numbers of technical graduates. Few of the colleges, themselves, however, have as yet done anything in the way of providing means to assist graduates in educational work after leaving college.

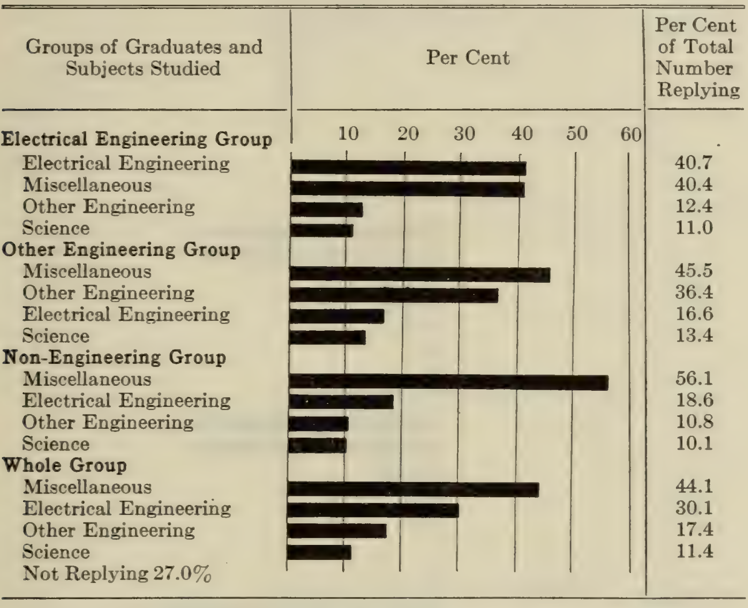
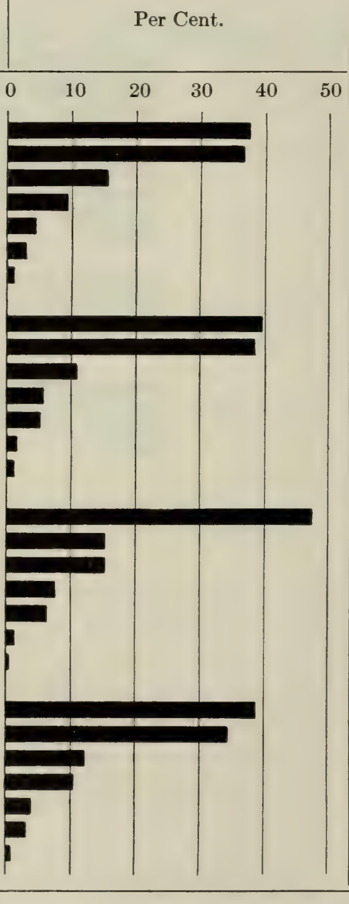


FIG. 12. Principal classes of subjects studied since graduation.

Subjects Studied.—Eta Kappa Nu men have systematically pursued one or more lines of study to an even greater extent than graduates in general. Figs. 12, 13 and 14 give the kinds of projects studied. It is to be noted that only about one-fifth of the entire number failed to indicate one or more subjects. General business heads the list, followed closely by higher technical engineering. After a considerable gap, come pure sciences, cultural subjects, law, mathematics and languages. These data are valuable aids to the colleges in establishing post-scholastic educational programs.



Groups of Graduates and Subjects Studied	Per Cent of Total Number Replying
Electrical Engineering Group	
Advanced Engineering	37.3
General Business	36.5
Pure Sciences	15.6
Cultural Subjects	9.1
Mathematics	4.6
Law	2.9
Foreign Languages	1.0
Other Engineering Groups	
Advanced Engineering	39.6
General Business	38.5
Cultural Subjects	10.7
Pure Sciences	5.9
Law	5.3
Mathematics	1.6
Foreign Languages	1.1
Non-Engineering Group	
General Business	47.5
Cultural Subjects	15.1
Advanced Engineering	15.1
Pure Sciences	7.9
Law	6.5
Mathematics	1.4
Foreign Languages	.7
Whole Group	
General Business	38.8
Advanced Engineering	34.1
Pure Sciences	12.2
Cultural Subjects	10.4
Law	4.0
Mathematics	3.4
Foreign Languages	.9

FIG. 13. Particular subjects studied since graduation.

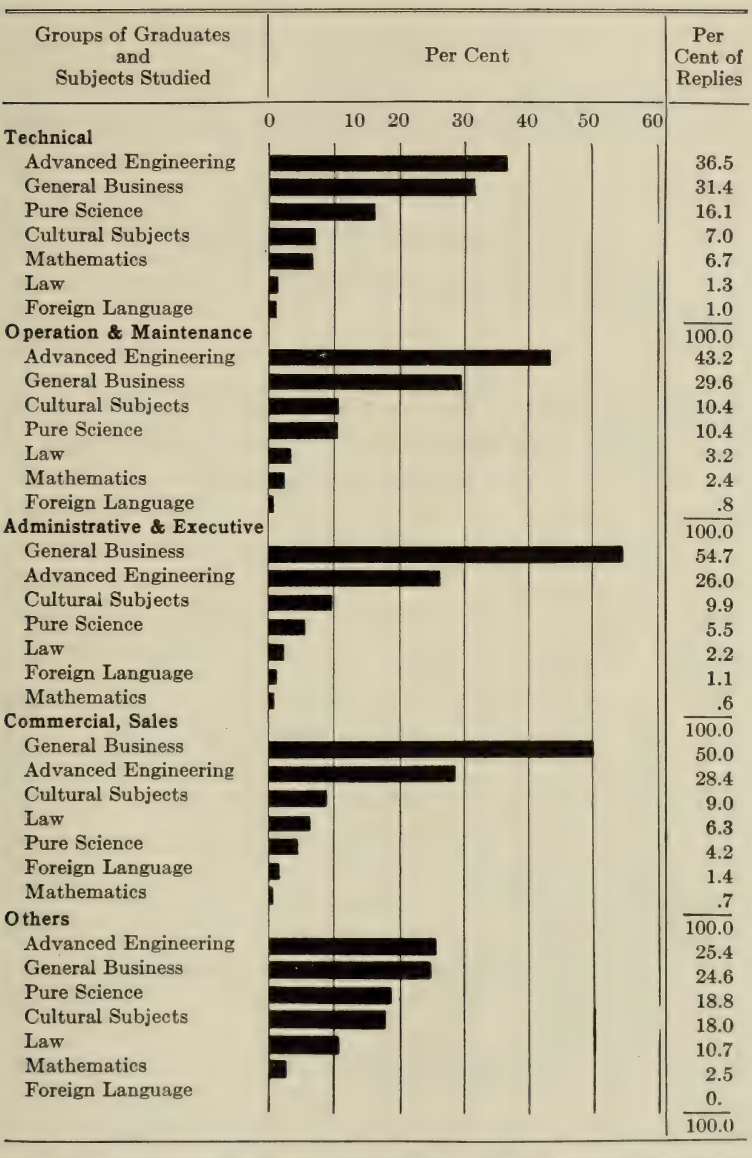


FIG. 14. Particular subjects studied by men in various functional activities.

BULLETIN NUMBER 9
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A SUMMARY OF OPINIONS CONCERNING ENGINEERING CURRICULA

Based Principally on Replies from Members of Engineering
Faculties, and Compared with Opinions of Graduates
and Prominent Engineers

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A SUMMARY OF OPINIONS CONCERNING ENGINEERING CURRICULA

Purposes.—The chief purpose of the present investigation of engineering education was stated at the time of its inception in the following sentence: "It is therefore proposed that the investigations of this Society be directed to a study of the objects of engineering education and the fitness of the present-day curriculum for preparing the student for his profession." In accordance with this purpose one division of the investigation has been devoted to studies of the engineering curriculum. Two groups of such studies have been made, one dealing with the content and arrangement of present-day curricula and the evolutionary changes through which they have reached their present form, and the other with the opinions of those most directly concerned as to the fitness of the curriculum for preparing the student for his profession.

Collateral Studies.—The study of the content and arrangement of engineering curricula has been carried out through the generous cooperation of the United States Bureau of Education. The results are given in Bulletin No. 10 of this series. The study of evolutionary changes in curricula has been made by the Staff, as named elsewhere, and recorded in Bulletin No. 11. Opinions regarding the curriculum have been gathered from three groups of individuals: Engineering graduates of institutions throughout the United States and Canada, influential members of the principal national engineering societies, and engineering teachers. These three groups will be referred to hereafter as "graduates," "engineers," and "teachers," respectively. Compilations of the opinions of graduates will be found in Bulletin No. 3; those of the engineers in Bulletin No. 12. The present bulletin deals primarily with the opinions of the teachers, but also includes comparisons of their opinions with those of the other groups.

Sources and Methods.—The questionnaire through which opinions of the teachers were obtained was prepared by the Staff and circulated through the cooperation of faculty committees in 137 institutions. Replies were received from 534 teachers in 115 institutions, a return of approximately sixty-seven per cent. An effort was made to obtain opinions chiefly from the more experienced teachers. It will be observed from the tabulations on pages 413 and 414 that this was accomplished. It will also be noted that teachers of engineering subjects predominate among those who furnished opinions, although there is a representation of teachers of other subjects. In all cases individual opinions were requested. In the collateral studies, 6,269 graduates and 855 engineers expressed themselves, returns of approximately forty and fifty-five per cent respectively. The compilation of replies and preparation of the summaries which follow were made by the Staff.

In order to facilitate the systematic compilation of replies, the questionnaire form was arranged so that answers could be given by entering check marks opposite appropriate items. Blank spaces were also provided in which additional statements of opinion could be entered. A great many of those who replied availed themselves of this opportunity to express themselves in their own words. These spontaneous comments not only furnish indices of the reasons underlying the opinions held, but also add thoughts which the formal answers do not bring out.

The material is presented in two groups: Part I is a general presentation and discussion of the results; and Part II, a numerical summary of the replies from teachers.

PART I. DISCUSSION OF OPINIONS

A. DIVERSITY OF CURRICULA

Past and Present Tendencies.—The extent to which curricula in the major divisions of engineering (civil, electrical, mechanical, etc.) should be differentiated from each other is an important problem in engineering education. In general the present tendency seems to be toward less distinct differentiation than was the case two or three decades ago. Students enrolled in the several curricula now pursue identical programs for the first year in most institutions. In more than one-fourth of the colleges the common program extends through two years and in a few cases through three years. Even after differentiation begins many subjects are common to all curricula.

Extent of Differentiation Favored.—The purpose of the question on this topic was to obtain a concensus of opinion as to how far this differentiation should be carried. Teachers and engineers were requested to indicate whether they believed curricula should be *sharply* differentiated; *moderately* differentiated, or only so as to assure concentration on a logically related group of technical subjects; or *slightly* differentiated, so as to give a broad, general engineering training. It will be observed from Fig. 1 that the consensus of opinion of the teachers is clearly in favor of a moderate degree of differentiation, five-eighths of the replies indicating that view. A considerably smaller proportion, about one-fourth, favor a slight degree of differentiation, while only about five per cent favor a sharp degree of differentiation. Less than five per cent of the teachers were non-committal. These opinions are summarized in detail on page 415 of Part II. Preferences of the engineers are about equally divided between slight and moderate degrees of differentiation. Both groups clearly believe that sharp differentiation of curricula is undesirable. If the opinions of the two groups are pooled, a moderate degree of differentiation is favored.

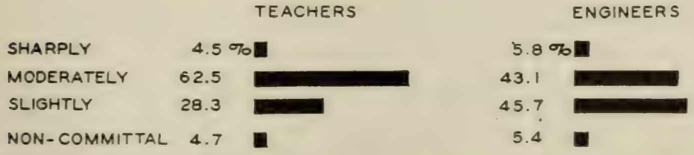


FIG. 1. Preference of teachers and engineers as to the degree of differentiation between the principal engineering curricula. (Percentage of teachers who indicated each item is shown.)

Two thoughts are frequently expressed by the engineers in their spontaneous comments on this topic: One the belief, apparently based on general grounds, that a broad training is the best preparation for the present-day needs of the engineer; and the other that college students are seldom able to predict the lines which their future endeavors will take and consequently should not be obliged to follow a program designed to fit them for some particular field. Several of the engineers cite their personal experiences as the basis for this view.

Comments of the teachers indicate that while they do not disagree with either of these opinions they feel that a moderate degree of differentiation is desirable because it affords concentration upon a logically related body of engineering material instead of a scattering over a wide range of subjects bearing little or no relationship to each other, and because such concentration serves to arouse and maintain the student's interest in his work.

Use of the Term Specialization.—The term ''specialization,'' as used in connection with engineering education is often applied to the subject of the preceding paragraphs, namely, the differentiation of instruction in accordance with the major divisions of engineering—civil, electrical, mechanical, etc. In the present discussion, however, it is used in a narrower sense and applied to the further degree of differentiation of curricula and instruction within the major fields themselves, such, for example, as the provision of distinct curricula in sanitary engineering, structural engineering and the like within the major field of civil engineering.

How Much Specialization is Warranted?—The extent to which such subdivison of curricula should be carried and the provision which should be made for preparing students to follow particular lines of engineering work is a much discussed problem. Three specific questions relating to it were submitted to the teachers: (1) whether or not engineering colleges should offer specialized undergraduate curricula in subdivisions of the major fields of engineering such as those mentioned above; (2) if so, whether such curricula should be offered by all, many, or few institutions; and (3) whether instruction in subjects applying primarily to one field of engineering only should serve to prepare for particular lines of work or whether it should serve primarily as means of teaching fundamental principles and engineering methods. Slightly more than half of the teachers who replied to the first question indicated that they favor the provision of curricula of the type described, but considerably more than half expressed the belief that such provision should be made in a few institutions only. There was nearly unanimous agreement in the opinion that the primary purpose of instruction in "specialized" engineering subjects should be to teach fundamental principles and methods rather than to train for particular kinds of work. Opinions of the engineers are in agreement with these views. The division of opinions of the teachers on these questions is given in tabular form on pages 415 and 416 of Part II and is shown graphically by Fig. 2.

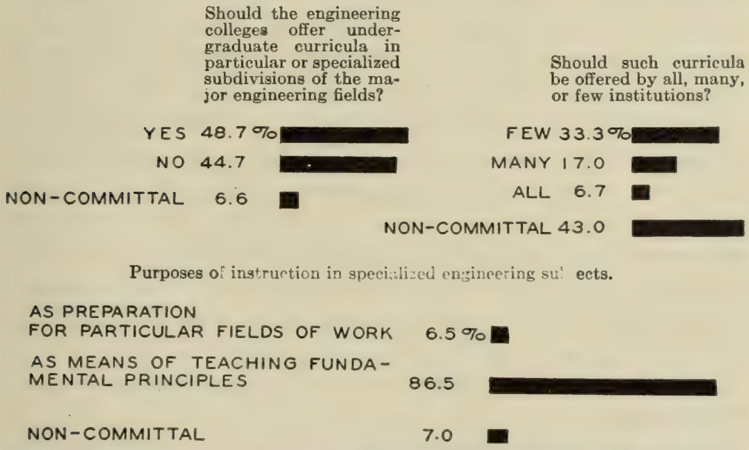


FIG. 2. Opinions of teachers as to specialization in engineering curricula.

Limitations of Specialization.—A large majority of both the teachers and the engineers availed themselves of the opportunity to express opinions on the topic of "specialization" in their own words. Apparently many hold strong beliefs on the subject. The thought most often expressed and strongly emphasized, particularly by the engineers, is that specialization is out of place in undergraduate curricula and that thorough grounding in fundamentals is of paramount importance. This belief, however, appears to be coupled with the thought that opportunity to pursue special lines of engineering study should be available, but only in the larger institutions or those specially equipped and manned to offer the work properly, and only then as graduate courses, or at most as options in the senior year. These views are expressed so frequently and in such forcible language as to indicate a strong majority conviction. The suggestion is also made that specialized courses should be offered in certain institutions in accordance with local conditions or needs. Several speak of the advantage of concentration by certain institutions on particular curricula and state that agreement should be reached by the colleges as to a proper division of the engineering field. They recognize, however, that it would be very difficult to make any apportionment of curricula among institutions in this manner. Many of the teachers express the belief that in teaching ''specialized'' engineering subjects there is no essential conflict between preparation for particular fields of work and training in fundamental principles and methods, although the latter should always be the primary purpose. If any one statement could adequately summarize the great number and diversity of opinions expressed it would probably be that specialization has a legitimate and necessary place in engineering education but that it should be confined to post-graduate courses and to those institutions which are qualified to offer the work as genuine professional study of high grade.

Suggested Functional Group of Curricula.—In the preceding paragraphs, differentiation and specialization have been discussed from the standpoint of the usual practice of providing curricula corresponding to the technical divisions of engineering. An entirely different type of classification may, however, be applied to the various kinds of engineering activity in accordance with their *functional* aspects, i.e., research, design, supervision, sales, etc. During the past few years the question has been raised as to whether or not the accepted and historic types of curricula properly satisfy the demand for men qualified for these functional types of service. Those who raise the question ask, for example, whether engineering graduates have been as well prepared for service in industry by curricula which differentiate between mechanical engineering and electrical engineering as they would have been by curricula which distinguish primarily between the engineering of design and the engineering of supervision. These questions were discussed and a proposed plan of curricula organized on functional lines was presented in a paper by Professor Edward Bennett which will be found in ENGINEERING EDUCATION for June, 1924. Without presenting a complete statement of the proposal or entering into any discussion of its merits, it may be said that the plan comprises two essential features: One is the provision of two grades of treatment, profoundly technical and moderately technical, for the fundamental subjects of the early years of the curriculum; and the other, the provision in the upper years of more extended and rigorous treatment of technical subjects for some students, and of less extended treatment of those subjects in combination with a wider range of commercial and non-technical subjects for others.

The introduction of such a plan would entail far-reaching changes of methods and organization. Advocates of the plan point out, however, that it would not only accord more nearly with the various functional activities of engineers but also with the differing abilities and inclinations of students.

Opinions on Functional Plan.—Questions relating to this matter were submitted to both engineers and teachers who were asked to state first, whether, in their opinion, there is merit in the principle upon which the plan is based, and second, whether or not it is worthy of a trial in one or more institutions. In their replies slightly more than half of the teachers expressed the belief that the principle upon which the plan is based has merit while approximately one-fourth believe that it has not. The balance were non-committal. Approximately one-half feel that the plan should be tried in one or more institutions; about eleven per cent feel that no trial is warranted. About forty per cent were non-committal. These opinions are summarized in greater detail on page 416. The engineers were somewhat less favorable both to the principle upon which the plan is based and to its proposed trial.

Replies of both groups are shown graphically in Fig. 3.

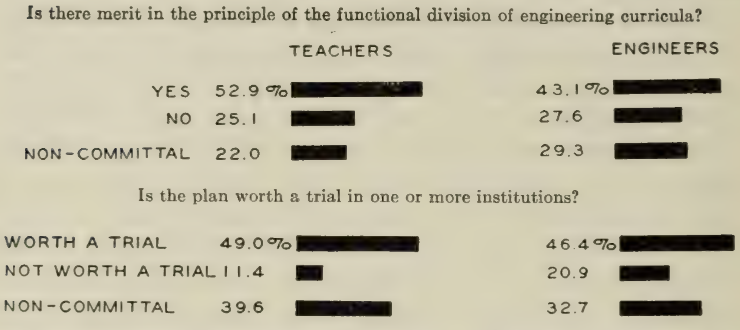


FIG. 3. Opinions of teachers and engineers as to functional division of curricula.

Comments on Functional Plan.—The general tone of the comments on the proposed plan of functional division of curricula is one of endorsement of the principle but skepticism as to its practicability. A number of teachers ask how the students are to be separated into the groups contemplated. Several feel that no valid means of separation are available and question whether any can be devised. Many, while frankly skeptical of the plan's practicability, would like to see it given a thorough trial. They state, however, that it could not be tried in their own institutions. One or two fear that the proposed moderately technical treatment of fundamental subjects might become superficial and thus have no value as a part of the training of an engineer.

B. SUBJECTS WHICH SHOULD BE INCLUDED IN ALL CURRICULA

The Swing Toward Fundamentals.—Of late years there has been a gradually increasing tendency in engineering education to concentrate on fundamental principles and methods and a corresponding swing away from instruction in the more specialized subjects. It is evident, as noted in a preceding paragraph, that this movement has the endorsement of engineers and teachers alike. It is therefore natural that much thought and discussion should have been devoted to the question of what constitute "fundamentals." Stated explicitly, the question is raised, "What subjects should constitute the common core of the engineering curriculum?" To the present time no general agreement has been reached on this matter and one of the chief purposes of the present study was to obtain a consensus of opinion upon it.

What Subjects Should be Required?—The question as to what subjects of instruction should be required in all curricula was therefore submitted to both teachers and practicing engineers. In order to facilitate answering the question a list of subjects was given and the respondents were requested to indicate those which they considered of fundamental importance. The list of subjects included those which are commonly required of all engineering students irrespective of the curriculum in which they are enrolled and also a considerable number of other subjects regarding which there might be some question. Spaces were also provided in which other subjects could be entered. The teachers were requested to indicate by the figure "1" those subjects which they considered of primary importance and by figure "2" those which they considered of secondary importance. The engineers were merely asked to indicate their selections by checkmarks. The resulting body of opinion, which is based upon the replies of over five hundred teachers of extended experience and more than eight hundred of the leading engineers of the country, is probably a good indication of present opinion on this matter.

The list of subjects indicated by a majority of the teachers as of primary importance is as follows:

Mathematics—through Calculus,
General Physics,
English—Composition and Speech,

Inorganic Chemistry,
General Economics,
Graphics—Mechanical Drawing and Descriptive Geometry,
Mechanics of Materials,
Analytical Mechanics,
Elements of Electrical Engineering,
Hydraulics,
Elements of Thermodynamics,
Surveying.

The practicing engineers indicated all of the foregoing and the following in addition:

Business Law,
Accounting,
Shop Work.

If the opinions of the two groups are pooled, the list is identical with that of the teachers with the single addition of Business Law.

In answer to another question which will be discussed more fully later, both teachers and engineers unmistakably indicated the belief that provision should also be made for cultural or humanistic subjects, though there was no majority agreement upon specific subjects. It may be inferred that opinions favor a rather wide range of cultural electives. It is clear, however, that the engineers and teachers believe that such subjects should be included in the common core of fundamentals.

The subjects selected, as described above, embody the ideas of engineering teachers as to the foundation of engineering curricula. It is evident that the concensus of opinion is in favor of curricula of predominantly scientific and technical content with the addition of an appreciable element of purely cultural subjects. A study of the time commonly alloted to the various subjects indicates that the core of fundamentals constitutes about two-thirds of the entire curriculum. This appears to be in harmony with the opinions previously cited as to the degree of differentiation and specialization deemed proper.

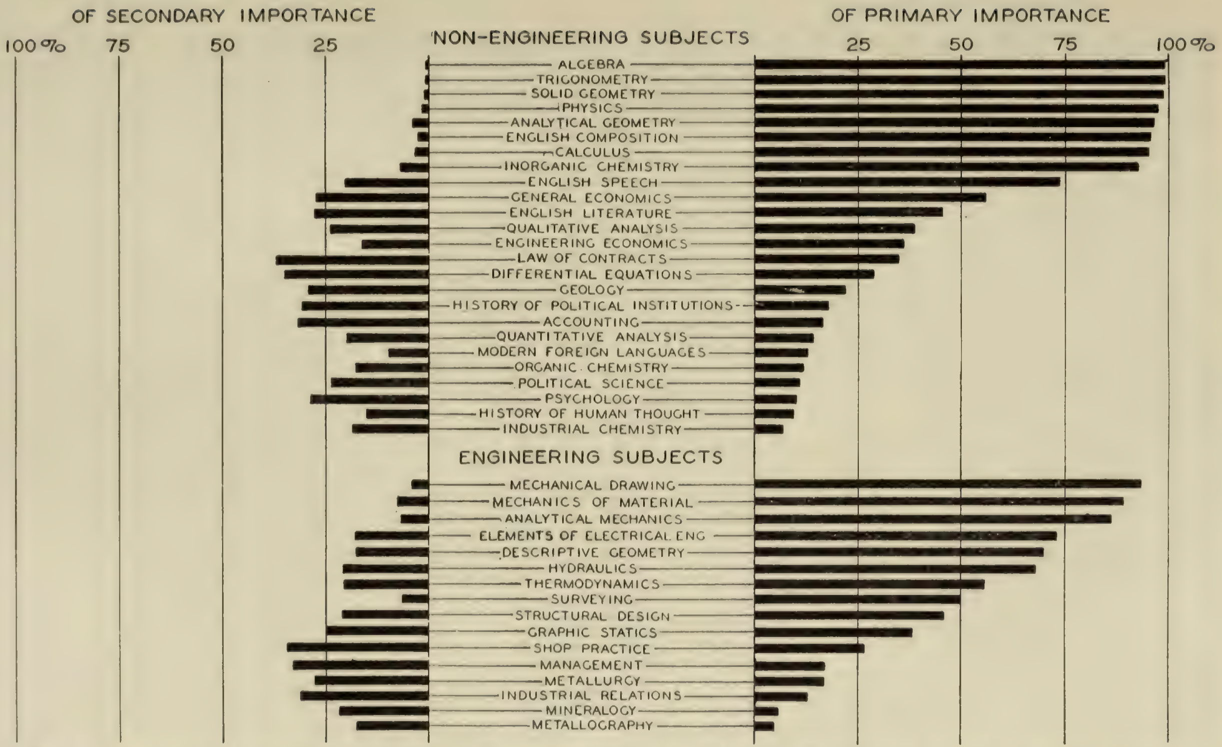


FIG. 4. Opinions of teachers as to subjects which should be included in all curricula in the principal divisions of engineering. (Percentages are based on number of teachers who indicated each subject. See page 29.)

Graphic Tabulation of Opinions.—A complete tabulation of the replies of the teachers to this question is displayed numerically on page 417 and graphically in Fig. 4.

Summary of Comments.—In commenting on the matter of fundamental elements in the engineering curriculum, many of the teachers expressed the view that several subjects not checked would be desirable additions if time permitted, but that the limitations of the four-year course made it undesirable to extend the list. A few teachers believe the curriculum should be lengthened so that the provision can be made for more fundamental subjects. Some feel that certain of the subjects, for example, solid geometry and trigonometry should be required for admission. A few teachers point out that while certain of the subjects, such as thermodynamics, should be required of all students, their treatment should be different for different groups. Some of the teachers add the comment that subjects not checked should be offered as electives, thus providing a proper range of selection for students of different aptitudes and interests.

C. Economic Content of Engineering Curricula

Importance of the Problem.—It has been aptly said that the engineer is a practical economist. Certainly it would be difficult to overestimate the economic importance of his work. To many, however, it appears that this is not reflected by commensurate provision in the curriculum for the economics of engineering. This belief was brought out early in the present investigation by the views expressed by practicing engineers and industrial leaders. Some of these were given in response to inquiries; others were unsolicited, spontaneous expressions. It was therefore decided to pursue the inquiry into this aspect of the curriculum further by submitting certain specific questions to the teachers and engineers.

Present Deficiencies.—The engineers were first asked to state whether, in the light of their experience, recent engineering graduates are as well qualified to deal with the economic aspects of engineering problems as they are to deal with their technical aspects. The same question was then asked as to the more experienced graduates. In reply, over ninety per cent stated that they find recent graduates not as well qualified to deal with the economic as with the technical phases of their work. Nearly seventy per cent expressed the same view as to graduates of five or more years' experience.

The graduates themselves throw light on this matter. In response to an inquiry, a majority of recent graduates named economics or related business subjects as the most serious omission from their college curricula. A large proportion also stated that they had pursued the study of these subjects after graduation.

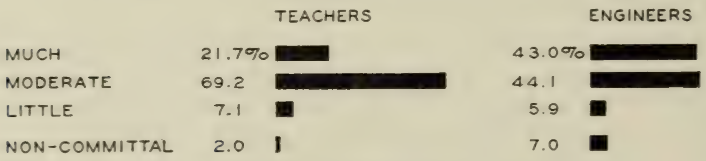
Emphasis to be Given.—Teachers and engineers were then asked to state whether, in their opinion, *much, moderate* or *little* emphasis should be given to the economic aspects of engineering in the undergraduate curriculum and to indicate means through which such emphasis could best be provided. In reply, approximately twenty-two per cent of the teachers felt that much emphasis is warranted, approximately sixty-nine per cent felt that moderate emphasis is desirable, while about seven per cent felt that little emphasis is needed. Two per cent were non-committal. The replies of the engineers were distributed as follows: Much—49 per cent, moderate—45 per cent, little—6 per cent.

It is quite clear that the engineers are more strongly in favor of extended training in economics and its application than are the teachers. Two explanations may be offered for this divergence of view: One, that engineers in active practice are more likely to be cognizant of the place which the solution of economic problems has in the engineer's activities; and the other, that the teachers, who are more closely in touch with methods pursued in college, do not believe that more extended courses in economics of the type now given would be valuable or that explicit training in the applied economics of engineering is practicable.

Methods and Means of Instruction.—As to the means through which instruction in economics and its applications to engineering problems should be given, the teachers and engineers were asked to state whether they prefer (1) more extended courses in general economics (political economy) of the type now generally provided; or (2) the addition of courses in practical economics given from the engineering point of view; or (3) the more general introduction of the economic element in the engineering subjects themselves. In reply to this question about one-fifth of the teachers indicated that more extended courses in general economics should be provided. Slightly more than one-half feel that both the addition of courses in practical economics and the stressing of the aspects of economy in the engineering subjects would be desirable. Approximately ten per cent of the teachers did not answer this question. About one-fourth of the engineers favor additional work in general economics; about the same proportion favor the addition of special courses in practical economics, while over sixty per cent believe that greater emphasis upon economy should be given in the engineering subjects proper. Table VI on page 418 summarizes the opinions of the teachers.

Graphical Summary of Opinions.—A graphical summary of these opinions is given in Fig. 5.

Emphasis which the economic aspects of engineering deserve:



Means favored for giving proper economic content and emphasis:
(A) By more extended courses in general economics
(B) By the addition of courses in "Engineering Economics"
(C) By greater emphasis on economic aspects of engineering subjects.
(Many teachers indicated more than one of the above methods)

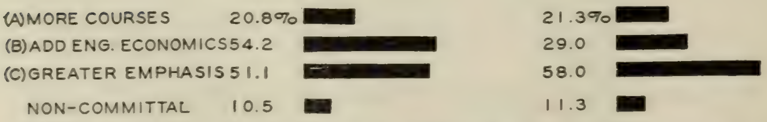


FIG. 5. Opinions of teachers and engineers as to instruction in economics and the economic aspects of engineering.

D. Instruction in Administration and Management

Recognition of the Problem.—In recent years increased attention has been given to the training of engineers for the managerial and administrative duties which they so frequently discharge. This trend in engineering education is shown by the fact that seventeen institutions now offer complete curricula in engineering administration, commercial engineering, industrial engineering, and the like. In addition, administration and management are frequently required as subjects of instruction in other curricula. In a few institutions they are required of all engineering students. The place which instruction in the realm of management should have in engineering education, whether it should be required of all students, whether it should be offered in separate curricula or given as part of others, and similar problems have not, however, been satisfactorily solved; at least there is no general agreement upon them. An effort was therefore made to obtain the concensus of opinion of engineers and teachers upon a few fundamental aspects of this matter.

Should Specific Instruction Be Given?—In answer to the question "Do you believe that all engineering students should receive specific instruction in the realm of administration and management?" slightly more than half of the teachers replied in the affirmative, about three-eighths in the negative, and the balance were non-committal. The replies of engineers to this question showed about the same distribution; fifty-seven per cent being in the affirmative, thirty per cent in the negative, and about thirteen per cent non-committal. The concensus is clearly in favor of specific instruction in this field.

Place in the Program.—As to whether separate curricula in administration and management should be offered or whether these subjects should be required in other courses, it is to be noted that approximately seventy per cent of the group of prominent members of the American Society of Mechanical Engineers to whom the question was submitted expressed the belief that these subjects should be taught as part of the mechanical engineering curriculum rather than separately. Only fifteen per cent felt that provision of complete, separate curricula is the more desirable plan. The opinions of engineers upon the question of the relative weight to be given to the technical and the administrative phases of engineering in the curriculum is indicated by the fact that a large majority of members of the American Society of Civil Engineers and the American Institute of Electrical Engineers favor predominantly technical courses followed by special business courses for those who wish to pursue them, in preference to predominantly business courses with some engineering work as the normal program. They apparently feel that the engineer is best prepared for his administrative and managerial duties by a thorough grounding in the technical aspects of his work. It is to be noted that a considerable proportion of the members of the three societies who expressed these views are themselves engaged in work which is primarily executive or administrative in nature.

Upon the question of whether administration and management should be included in all, or merely in certain, curricula, a majority of the teachers, as previously stated, expressed the view that such instruction should be required in all courses. Those who felt otherwise were asked to specify the curricula in which these subjects should be included. In reply, the mechanical engineering curriculum was mentioned most frequently, followed by preference for an optional provision in all curricula, and by electrical engineering as a third choice.

A detailed summary of the replies to questions on this topic will be found in Part II, page 418.

Summary of Comments.—Although a majority of the teachers who replied to questions relating to administration and management felt that instruction in these subjects should be given to all engineering students, those who commented on the matter were inclined to point out objections. The thought most often reiterated was that work of this character should be left either to post-graduate years in college or to independent study after graduation. A few took the position that these subjects are not sufficiently concrete to warrant inclusion in an already crowded curriculum at the expense of technical and scientific subjects which, in their opinion, are susceptible of more definite treatment. Quite a number felt that while instruction in administration and management should be required in certain curricula, generally those relating most closely to the manufacturing industries, all students should not be required to pursue such courses. The comments of both teachers and engineers reflect the condition previously mentioned; namely, that there is no general agreement on these matters and that the institutions are attacking the problem by different methods and from divergent standpoints.

E. CULTURAL SUBJECTS

Use of the Word "Cultural."—The word "cultural," as applied to subjects of the engineering curriculum, is very generally used to designate the group of non-professional, humanistic subjects which includes English literature, history, economics, foreign languages, and the like. It by no means follows that the engineering subjects themselves lack cultural value; in fact, the teaching of science or engineering may be, and often is, more liberalizing than routine drill in some of the so-called "cultural" subjects. The term has, nevertheless, come to have the general usage mentioned and it was felt that its application would be understood by those to whom questions relating to this portion of the curriculum were submitted.

Importance in the Curriculum.—That cultural subjects should constitute a prescribed part of the curriculum seems to be generally accepted as a fundamental principle. At the present time approximately nineteen per cent of the required subjects of the engineering curriculum fall within this class, this being the average for institutions in the United States. Endorsement of the principle is clearly given by the answers of teachers to a question as to whether subjects of purely cultural value should be required of all engineering students, since approximately two-thirds replied in the affirmative and only about one-fifth in the negative, the balance being noncommittal.

As to the extent of provision which should be made for these studies, about one-eighth of the replies indicated that they should be given considerable emphasis and an important place in the curriculum, about one-half that moderate emphasis and time should be devoted to them, and only about one-sixth that they should be given a place of minor importance. Graduates hold much the same view, all but about fourteen per cent stating that, in their opinion, cultural subjects are of sufficient value to warrant their inclusion. Approximately fifty-seven per cent rate them as of ''considerable'' or ''great'' importance, while over one-fourth indicate the belief that they are ''indispensable to their intellectual development.''

Choice and Distribution.—If cultural subjects are to be given an important place in the curriculum, the questions naturally arise: How shall these subjects be distributed throughout the four years, and what particular subjects shall be offered? In answer to the first of these questions, approximately sixty per cent of the teachers expressed the belief that cultural subjects should be offered or required throughout all four years instead of during the first two years only, as was the almost universal custom until quite recently and is still a common practice.

In answer to the second question, the teachers named a considerable number and variety of cultural subjects; literature, history, economics, modern foreign languages, philosophy, and political science being mentioned most frequently. Only literature, however, was favored by a majority.

Fig. 6 shows the replies to the above questions graphically.

Comments on Cultural Subjects.—Although space limitations of the questionnaire did not permit discussion of the manner in which the word ''cultural'' was used, comments of the teachers indicated that there was little or no misunderstanding of the intent. Quite a number, however, objected to this narrow use of the term and stated that all subjects, if properly taught, have cultural value. Comments were decidedly favorable to the requirement of cultural studies. Many of the teachers pointed out that these subjects are likely to be of the greatest value and interest if given in the later years. Several made the comment that cultural studies should be included to give balance to the curriculum and to provide the student with fields of interest outside of his scientific and technical subjects. Quite a number deplored the fact that the necessity of giving adequate attention to fundamental scientific and technological studies restricted the time available for cultural subjects.

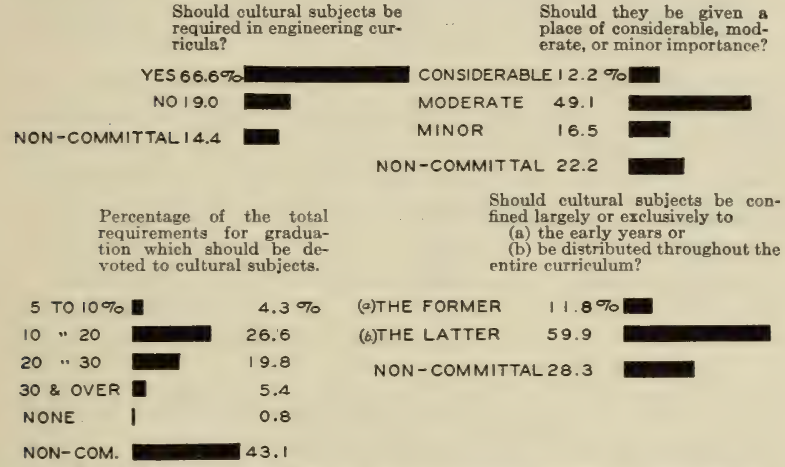


Fig. 6. Opinions of teachers as to the cultural content of engineering curricula.

Cultural subjects which were mentioned as desirable additions to the list given above show a wide and interesting range: Appreciation of Music, History of Architecture, History of Science, Ethics, Evolution, Comparative Religion, History of Art, and many others. This diversity of preferences is a further indication of the view expressed by many that students should be permitted a considerable range of selection rather than required to pursue a few prescribed subjects.

Modern Foreign Languages.—No other subject or group of subjects of the engineering curriculum has suffered the same attrition in the past fifty years as modern foreign languages. The question of their exclusion or inclusion has not been finally settled, however, and there are many who deplore the present condition. The matter was therefore submitted to teachers, engineers, and graduates in the hope of obtaining a clear cut expression of views.

Without giving a detailed analysis of the replies, it may be said that a large majority indicated the belief that foreign languages, as now taught, are not of sufficient value either as purely cultural subjects or from the standpoint of their practical or "tool" value to warrant their inclusion in the engineering curriculum.

In the matter of the practical value of language study, the replies of the engineers, when asked to state the extent to which they had used their knowledge of foreign languages in connection with their professional or business activities, are interesting. These replies were distributed as follows:

Much	9.3%
Moderately	22.7
Little	39.0
None	27.6
Unstated	2.4

It should be remembered that these engineers include the more prominent members of the profession who might be expected to find greater use for foreign languages than the majority.

An indication of the view of graduates on this matter is given by the fact that in a list of those subjects which they consider of least value modern foreign languages are named nearly as often as all others combined.

Summary of Views on Foreign Languages.—Fig. 7 summarizes the views of engineering teachers on this matter. For tabular summary, see pages 420, 421 and 422 of Part II.

In their spontaneous comments many teachers who felt that foreign languages should not be *required* indicated the opinion that they should be *offered* as electives. Quite a number felt that engineers should have a knowledge of at least one foreign language but believed that it should be acquired before admission to college. Most of the teachers seem to believe that it is impracticable to provide enough time in a four-year engineering curriculum to teach foreign languages effectively and that their exclusion, while to be deplored, is necessary unless the course is lengthened.

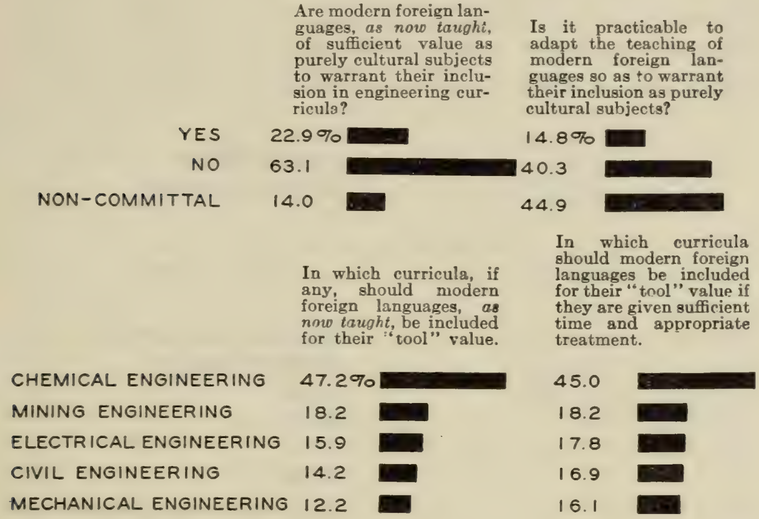


FIG. 7. Opinions of teachers as to modern foreign languages in engineering curricula.

F. SHOP COURSES

Questions Raised.—While probably not one of the major issues in engineering education at present, the general matter of shop courses and certain specific problems relating to them have received considerable discussion. In an effort to obtain some light on these matters, the following questions were submitted to the engineers and teachers:

1. Should shop work be required in all engineering curricula?
2. Should summer employment be substituted for or required in addition to shop work in college?
3. What principal purposes should college instruction in shop work serve?
4. What should be the plan upon which shop courses should be organized and conducted?

Summary of Opinions.—The answers to these questions may be briefly summarized as follows:

1. It is evident that many believe that shop work should not be required of all students, but only of those enrolled in curricula most closely related to the manufacturing industries. Both teachers and engineers are in agreement in this view.

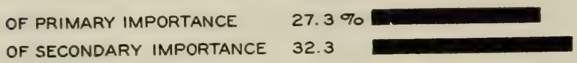


Fig. 8*A*. Opinions of teachers as to the importance of shop courses as fundamental elements in all engineering curricula.

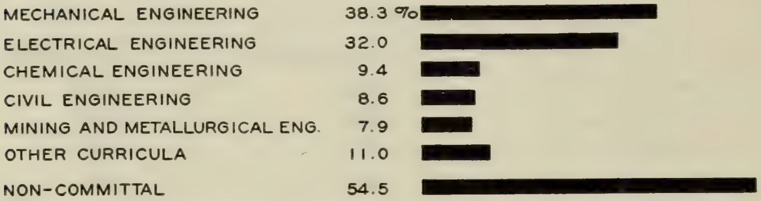
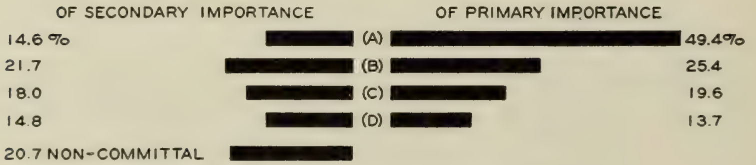


Fig. 8*B*. Opinions as to curricula in which shop courses should be required.



(*A*) Training in the technique of shop operations.
(*B*) Training in the methods of shop management.
(*C*) Imparting of knowledge of the economic phases of shop operations.
(*D*) Development of skill in the handling of tools and machines.

Fig. 8*C*. Opinions as to the primary purposes of shop courses.

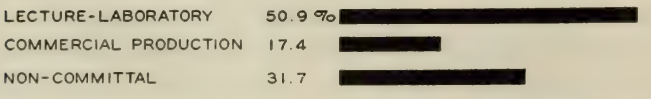


Fig. 8*D*. Opinions as to methods which should be employed in organizing shop courses.

2. It is the majority opinion that summer employment should not be substituted for required shop work in college, though many feel that such employment would serve as a valuable adjunct if properly systematized and administered.

3. Knowledge of the technique of shop operations, and acquaintance with principles of shop management, are regarded as the primary purposes of shop courses, while the development of manual skill and the ability to handle tools and machines is regarded as an entirely subordinate objective.

4. The method of organizing and conducting shop courses on the lecture-laboratory plan as commonly pursued in engineering colleges was preferred to that of an approximation to commercial production methods. Slightly more than one-half of the teachers favored the former, about one-sixth the latter, while about one-third were non-committal.

The replies to these and one or two other questions relating to shop courses are displayed numerically on page 423 and graphically in Fig. 8.

Comments upon the matter of shop courses added very little to the answers to the formal questions. Quite a number of teachers expressed the opinion that shop work had been very much overdone in the past and that the time devoted to it should be materially reduced. A number also felt that there should be a new conception of the purposes of shop work since much of it in the past had been mere manual training without any adequate appreciation of the broader possibilities of shop instruction. It is fair to state, however, that this criticism can not properly be made of the work of many institutions as conducted at present.

G. COORDINATION OF SCIENCES AND TECHNICAL SUBJECTS

Is Coordination Needed?—As a final purpose of this study, an effort was made to obtain views on the much discussed problem of the means of obtaining a proper degree of coordination in the teaching of closely related subjects of the engineering curriculum. This was done for the reason that one of the criticisms most frequently made of engineering education is that such coordination is seriously lacking.

In submitting this topic to the teachers, the first effort was to obtain a concensus of opinion upon the principles which should underlie the teaching of the fundamental mathematics and sciences. Specifically, the teachers were asked to state whether, in their opinion, instruction in mathematics and the physical sciences should be based upon the principle that knowledge of those subjects is primarily an end in itself and that preparation for the subsequent engineering subjects, while important, is secondary; or whether instruction in these basic subjects should be upon the principle that they are to serve primarily as tools in the subsequent engineering subjects. The replies indicated that a considerable majority hold the latter view, namely, that preparation for the subsequent dependent engineering subjects should be the primary aim. It must be remembered, however, that there was a large preponderance of teachers of engineering subjects among those who expressed this view. A careful study of the questionnaires, however, showed that a significant fraction of the teachers of mathematics and science agree with the views of the teachers of the engineering subjects proper.

Means of Coordination.—As to means which may be employed to bring about better coordination of instruction in related scientific and technical subjects, the teachers were inclined to recommend that mathematics and the physical sciences be taught either by engineers or by those possessing the engineering point of view and having some familiarity with engineering methods. The introduction of practical engineering problems as illustrations of mathematical and physical laws was also mentioned as a desirable means of promoting coordination. Conferences between the teachers of various departments of instruction and other methods which naturally suggest themselves were also mentioned.

A summary of the replies to these questions will be found in Part II, page 424.

H. CONCLUSION

Synthesis of Opinions.—In the entire body of opinions cited and analyzed in this bulletin there is discernible a fairly consistent conception of what engineering curricula should be. The more fundamental aspects of this conception may be epitomized by the following characterizations:

1. Moderate diversity, but tending away from specialization;
2. Dominance of scientific and broadly technical content and emphasis;
3. Inclusion of a well-identified core of required subject matter in common;
4. Inclusion at all stages of subjects of purely cultural value;
5. Due emphasis (though not predominant) on the economic aspects of engineering and on its concern with administration and management;
6. Coherence of arrangement and coordination of related subjects;
7. Thoroughness rather than completeness of detail.

PART II. NUMERICAL SUMMARY OF REPLIES BY MEMBERS OF THE ENGINEERING FACULTIES

I. SOURCES OF REPLIES

Number of institutions from which replies were received	115
Response in per cent of 137 institutions canvassed	84.7
Number of questionnaires received	534
Response in per cent of questionnaires distributed	67.0

TEACHING RANK

	No.	%
Professors	381	71.5
Deans	48	9.0
Associate Professors	46	8.6
Assistant Professors	42	7.8
Instructors	9	1.7
Presidents	4	.7
Unstated	4	.7

YEARS OF TEACHING EXPERIENCE

Years	No.	%
1 to 5	33	6.2
6 to 10	88	16.5
11 to 15	94	17.6
16 to 20	106	19.9
21 to 25	78	14.6
26 to 30	53	9.9
31 to 35	28	5.2
36 to 40	16	3.0
Over 40	8	1.5
Unstated	30	5.6

DEPARTMENT OR PRINCIPAL SUBJECT

	No.	%
Civil Engineering	130	24.4
Mechanical Engineering	102	19.1
Electrical Engineering	90	16.9
Chemical Engineering	46	8.6
Mining Engineering	26	4.9
Mathematics	22	4.1
Physics	22	4.1
Mechanics	18	3.8
Drawing	11	2.0
Architectural Engineering	9	1.7
English	7	1.3
Economics	6	1.1
Metallurgy	5	.9
Industrial Engineering	5	.9
Agricultural Engineering	5	.9
Thermodynamics	4	.7
Structural Engineering	4	.7
Ceramics	3	.5
Hydraulics	3	.5
Language	2	.3
Experimental Engineering	2	.3
Highway Engineering	2	.3
Shop Practice	1	.2
Fire Prevention Engineering	1	.2
Petroleum Engineering	1	.2
Sanitary Engineering	1	.2
Aeronautical Engineering	1	.2
Textile Engineering	1	.2
Unstated	5	.9

II. Differentiation of Curricula

1. Replies favoring undergraduate curricula in the major engineering fields which are

	No.	%
Slightly differentiated	151	28.3
Moderately differentiated	334	62.5
Sharply differentiated	24	4.5
Unclassified	9	1.7
Unstated	16	3.0

2. Proportion of curricula common to all of the major branches:

Per Cent	No.	%
20 to 30	3	2.6
30 to 40	7	6.1
40 to 50	10	8.7
50 to 60	40	34.8
60 to 70	28	24.4
70 to 80	15	13.0
80 to 90	9	7.8
Unstated	3	2.6

III. Specialization

1. Should the engineering colleges offer undergraduate curricula in particular or specialized subdivisions of the major engineering fields?

	No.	%
Yes	260	48.7
No	239	44.7
Unclassified	18	3.4
Unstated	17	3.2

2. If so, should such curricula be offered by all, many, or few institutions?

	No.	%
Few	176	33.3
Many	91	17.0
All	36	6.7
Unclassified	195	36.3
Unstated	36	6.7

3. Replies indicating that instruction in specific engineering subjects which apply to a particular field of engineering should be based upon the principle that the aim is to

	No.	%
Prepare men for particular fields of work	35	6.5
Afford means of teaching fundamental principles	462	86.5
Unclassified	24	4.5
Unstated	13	2.5

IV. FUNCTIONAL VS. TECHNICAL DIVISIONS OF CURRICULA

1. In your opinion is there merit in the principle upon which the functional plan is based?

	No.	%
Yes	283	52.9
No	134	25.1

2. If so, is it worthy of a serious trial in one or more institutions?

	No.	%
Yes	262	77.1
No	61	18.0
Unclassified	17	4.9

V. FUNDAMENTAL ELEMENTS IN ALL ENGINEERING CURRICULA

NON-ENGINEERING SUBJECTS	Of Primary Importance.		Of Secondary Importance.	
	No.	%	No.	%
Algebra	526	98.8	1	0.19
Trigonometry	526	98.8	1	0.19
Solid Geometry	523	98.4	10	1.9
Physics	519	97.2	8	1.5
Analytical Geometry	512	96.2	21	3.9
English Composition	510	95.5	13	2.4
Calculus	508	95.4	18	3.3
Inorganic Chemistry	493	92.5	36	6.7
English Speech	392	73.5	112	21.0
General Economics	297	55.7	145	27.2
English Literature	242	45.5	147	27.5
Qualitative Analysis	204	38.3	128	24.0
Engineering Economics	191	35.9	86	16.1
Law of Contracts	185	34.7	196	36.8
Differential Equations	154	29.0	186	35.0
Geology	117	22.0	156	29.2
History of Political Institutions	94	17.6	164	30.7
Accounting	86	16.1	169	31.7
Quantitative Analysis	75	14.0	108	20.1
Modern Foreign Languages	66	12.4	186	34.9
Organic Chemistry	61	11.4	95	17.8
Political Science	57	10.7	127	23.8
Psychology	53	10.0	152	28.5
History of Human Thought	49	9.2	81	15.2
Industrial Chemistry	35	6.5	99	18.5
ENGINEERING SUBJECTS				
Mechanical Drawing	498	93.5	23	4.3
Mechanics of Materials	475	89.0	40	7.5
Analytical Mechanics	458	86.0	33	6.2
Elements of Electrical Engineering	389	72.9	95	17.8
Descriptive Geometry	373	70.0	93	17.4
Hydraulics	360	67.5	111	20.8
Thermodynamics	295	55.5	110	20.6
Surveying	267	50.0	166	31.2
Structural Design	244	45.8	112	21.0
Graphic Statics	202	37.9	133	25.0
Shop Practice	141	26.5	182	34.2
Management	91	17.0	176	33.0
Metallurgy	88	16.5	146	27.3
Industrial Relations	67	12.5	165	31.0
Mineralogy	31	5.8	113	21.2
Metallography	26	4.8	92	17.2

VI. Economic Content of Engineering Curricula

1. The economic aspect of engineering is of such importance as to warrant

	No.	%
Little emphasis	38	7.1
Moderate emphasis	370	69.2
Much emphasis	116	21.7
Unclassified	5	1.0
Unstated	5	1.0

2. The application of economic principles to engineering problems should be given

	No.	%
By more extended courses in general economics	111	20.8
By addition of courses in practical economics	290	54.2
By stressing the economic aspect in the present engineering subjects	273	51.1
Unclassified	2	.4
Unstated	54	10.1

VII. Administration and Management

1. Do you believe that all engineering students should receive specific instruction in the realm of administration and management?

	No.	%
Yes	279	52.2
No	200	37.4
Unclassified	4	.8
Unstated	51	9.6

2. If you believe that such instruction should not be included in all curricula but should be included in certain curricula please name those in which it should be included.

	No.	%
Mechanical Engineering	33	6.2
Electrical Engineering	16	3.0
Industrial Engineering	10	1.9
Chemical Engineering	6	1.2
Civil Engineering	3	.6
Mining and Metallurgy	3	.6
Other curricula	7	1.4
As options in all curricula	20	3.8
In no curricula	7	1.3
Unclassified	57	10.7
Unstated	397	74.1

VIII. CULTURAL CONTENT OF ENGINEERING CURRICULA

1. Should courses of purely cultural value be required in engineering curricula?

	No.	%
Yes	356	66.6
No	101	19.0
Unclassified	62	11.6
Unstated	15	2.8

2. If so, should they be given a place of considerable, moderate, or minor importance?

	No.	%
Considerable	65	15.4
Moderate	262	62.2
Minor	88	20.9
Unclassified	6	1.4

3. Approximately what percentage of the total requirements for the degree should be devoted to subjects which are primarily of cultural value?

Per Cent	No.	%
5 to 10	23	4.3
10 to 15	92	17.2
15 to 20	50	9.4
20 to 25	62	11.6
25 to 30	44	8.2
30 to 35	14	2.6
Over 35	15	2.8
None	4	.8
Unclassified	32	6.0
Unstated	198	37.1

4. Should cultural subjects be confined largely or exclusively to the early years or should they be distributed throughout the entire curriculum?

	No.	%
The former	63	11.8
The latter	320	59.9
Unclassified	42	7.9
Unstated	109	20.4

5. What subjects would you recommend as particularly valuable or desirable elements of the cultural content of engineering curricula?

	No.	%
Literature	277	52.0
History	246	46.0
Modern Languages	133	24.9
Psychology	109	20.4
Economics	92	17.2
Philosophy	91	17.0
Political Science	86	16.1
Art	43	8.1
Biology	33	6.2
Geology	23	4.3
Others	37	7.1
Unclassified	23	4.3
Unstated	167	31.2

IX. MODERN FOREIGN LANGUAGES

1. Are modern foreign languages as now taught of sufficient value as purely cultural subjects to warrant their inclusion in engineering curricula?

	No.	%
Yes	122	22.9
No	337	63.1
Unclassified	17	3.2
Unstated	58	10.8

2. If your answer to the above is "No" please state whether you believe it is practicable so to adapt the teaching of modern foreign languages as to warrant their inclusion in engineering curricula as purely cultural subjects.

	No.	%
Yes	79	25.3
No	215	68.9
Unclassified	18	5.8

3. Please indicate in which, if any, of the following curricula modern foreign languages *as now taught* should be included from the point of view of their practical or ''tool'' value.

	No.	%
Chemical Engineering:		
Yes	252	47.2
No	35	6.5
Unclassified	13	2.5
Unstated	234	43.8
Mining Engineering:		
Yes	97	18.2
No	87	16.3
Unclassified	12	2.5
Unstated	338	63.2
Electrical Engineering:		
Yes	85	15.9
No	76	14.2
Unclassified	6	1.2
Unstated	367	68.7
Civil Engineering:		
Yes	76	14.2
No	109	20.4
Unclassified	11	2.1
Unstated	338	63.3
Mechanical Engineering:		
Yes	65	12.2
No	110	20.6
Unclassified	7	1.3
Unstated	352	65.9

4. Please indicate in which, if any, of the following curricula modern foreign languages, *if given sufficient time and appropriate treatment,* should be included from the standpoint of their practical or "tool" value.

	No.	%
Chemical Engineering:		
Yes	240	45.0
No	14	2.6
Unclassified	60	11.2
Unstated	220	41.2
Mining Engineering:		
Yes	97	18.2
No	39	7.3
Unclassified	48	9.0
Unstated	350	65.5
Electrical Engineering:		
Yes	95	17.8
No	63	11.8
Unclassified	46	8.6
Unstated	330	61.8
Civil Engineering:		
Yes	90	16.9
No	64	12.0
Unclassified	85	15.9
Unstated	295	55.2
Mechanical Engineering:		
Yes	86	16.1
No	63	11.8
Unclassified	41	7.7
Unstated	344	64.4

X. SHOP COURSES

1. Curricula in which shop courses should be required:

	No.	%
Mechanical Engineering	205	38.3
Electrical Engineering	171	32.0
Chemical Engineering	50	9.4
Civil Engineering	46	8.6
Mining and Metallurgy	42	7.9
Industrial Engineering	15	2.8
Agricultural Engineering	7	1.3
As an elective	4	.8
Other curricula	9	1.8
Considered uncollegiate	23	4.3
Unclassified	10	1.9
Unstated	282	52.6

2. Summer employment in shops should be required:

	No.	%
In lieu of similar work in college	135	25.3
In addition to similar work in college	142	26.6
Unclassified	30	5.7
Unstated	227	42.4

3. If systematic shop instruction is given to students in college, which of the following should be its purposes?

	Of Primary Importance.		Of Secondary Importance.	
	No.	%	No.	%
Knowledge of the technique of shop operations	264	49.4	78	14.6
Knowledge of the methods of shop management	136	25.4	116	21.7
Knowledge of the economic phases of shop operations	105	19.6	96	18.0
Skill in handling tools and machines	73	13.7	79	14.8

	No.	%
Unclassified	7	1.3
Unstated	104	19.4

4. Which of the following methods should be employed in organizing shop courses?

	No.	%
Lecture-laboratory	272	50.9
Commercial production	93	17.4
Unclassified	17	3.2
Unstated	152	28.5

XI. Coordination of Sciences and Technical Subjects

1. Is it a correct premise to lay down that instruction in mathematics and the physical sciences should be based upon the principle that knowledge of these subjects is primarily an end in itself and that preparation for the subsequent dependent engineering subjects, while important, is secondary?

	No.	%
Yes	95	17.8
No	364	68.2
Unclassified	39	7.3
Unstated	36	6.7

2. Or, should instruction in these subjects be based upon the principle that they are to serve primarily as tools in the subsequent engineering subjects?

	No.	%
Yes	342	64.0
No	69	12.9
Unclassified	30	5.7
Unstated	93	17.4

3. If the latter (No. 2 above) is considered the correct premise, what measures may be taken more closely to coordinate instruction in mathematics and the sciences with the engineering subjects to which they are prerequisite?

	No.	%
Teachers should be engineering graduates or have the engineering viewpoint	178	53.8
Practical engineering problems	68	20.5
Cooperation between departments	53	16.0
Mathematics department should be under the engineering department	18	5.4
Better texts	8	2.4
Grouping of students with similar aims	1	0.3
Unclassified	5	1.5

4. Is there necessity or desirability of limiting the ground covered in these subjects so as to provide for greater thoroughness than at present?

	No.	%
Yes	254	47.5
No	151	28.3
Unclassified	50	9.4
Unstated	79	14.8

BULLETIN NUMBER 10
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF
ENGINEERING CURRICULA

by
Walton C. John, Ph.D.,
Specialist in Graduate and Professional Education,
Bureau of Education, U. S. Department of the Interior

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A STUDY OF ENGINEERING CURRICULA

BY WALTON C. JOHN,

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Purposes.—This study deals with the requirements for entrance and for graduation in the colleges which grant first degrees in engineering. The five curricula of widest occurrence and largest enrollment are included, namely: Civil, mining, mechanical, electrical and chemical engineering. The treatment is primarily quantitative and aims to indicate what is taught and in what proportions rather than what should be taught. Under given conditions it may be shown that the lengthening of the course of study or the expansion of the curriculum may make possible marked improvement in the quality of education, and on the other hand there are examples indicating that reduction may be made in total or specific requirements and make more efficient work possible under the circumstances. Thus it appears that the quantitative and the qualitative aspects of the matter cannot readily be dissociated.

It is hoped that the facts thus organized may assist the curriculum maker in arriving at necessary readjustments, whether by lengthening or shortening courses of study, by improving their coordination or by making more logical their sequences.

Plan of Presentation.—The present study exhibits both entrance requirements and curricula as analyzed into groups of closely related subject matter under the following heads: English, mathematics, physical sciences, social sciences, foreign languages, physical and military training, miscellaneous non-engineering subjects, non-engineering electives, the principal engineering subject of the particular curriculum, other engineering subjects, and engineering electives. The requirements are shown for individual institutions, together with maximum, minimum and median figures and with an indication of distribution and of modal tendencies. Part I presents in graphic form the combined requirements for the eight-year period of preparation and instruction under direct and indirect control of the colleges of engineering. Average figures are given for both publicly and privately controlled institutions. Part II is a comparative summary and analysis of graduation requirements in the five curricula studied, together with a comparison of engineering curricula with curricula in agriculture. Part III is a summary and a detailed analysis of entrance requirements. Part IV comprises the detailed analysis of graduation requirements in the several curricula by institutions. The more general features of the study are covered in Parts I and II.

Scope.—Ninety-two colleges which award first degrees in engineering are included in one or more features of the study. All are located in the United States. Sixty of these institutions are under public control and thirty-two are under private control. The group as a whole includes slightly more than sixty per cent of all the colleges of this type in the United States and is believed to be quite representative within the range of normal conditions. The complete list of colleges included is given on pages 446 to 448, inclusive.

The analysis of entrance requirements includes all the institutions in this list. It was found necessary, however, to omit from the analyses of graduation requirements a few institutions for which the data can not readily be made to correspond to the data for the group as a whole. Thus, the University of Cincinnati, the University of North Carolina and the Municipal University of Akron are omitted because of the cooperative plan on which their curricula are organized; while Rensselaer Polytechnic Institute and Worcester Polytechnic Institute are omitted because of difficulty in reducing their graduation requirements to semester-hour credits. Not all of the remaining eighty-seven institutions offer all of the curricula studied. The net result is that the analysis of the civil engineering curriculum is based on eighty-three institutions, the mining engineering curriculum on twenty-five, the mechanical engineering curriculum on seventy-six, the electrical engineering curriculum on seventy-eight, and the chemical engineering curriculum on fifty-five. The data for several colleges which operate on a quarter basis have been reduced to equivalent semester-hours.

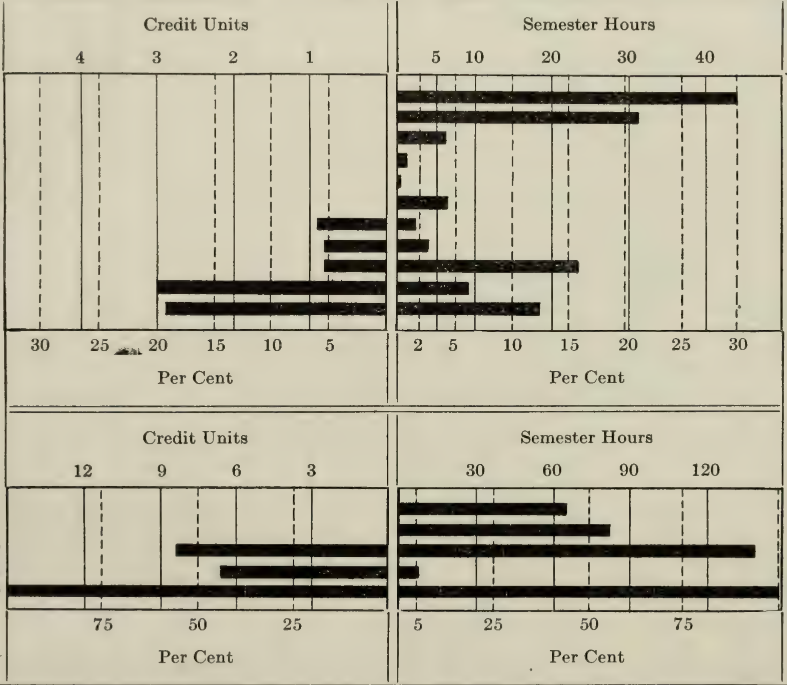
Sources of Information.—The primary data were taken from the catalogs of the several institutions for the academic year of 1924–25 and were checked in most cases by the deans or the registrars. In some instances where verification was not obtainable the author was able to include the information desired because of the clear statements of the catalogs.

PART I. GRAPHICAL SUMMARIES OF COMBINED REQUIREMENTS FOR ADMISSION AND FOR GRADUATION

Relations Shown.—The following series of graphs brings together the principal features of the analyses of both groups of requirements in two sets of general pictures, one set for the publicly controlled and the other for the privately controlled institutions. The data shown to the left of the central division of each chart are the average entrance requirements, expressed both in high school units and as percentages of the total. The data immediately to the right of the central division are the average graduation requirements, expressed in semester-hour units and as percentages of the total. At the extreme right are shown the combined entrance and graduation requirements expressed as percentages of the total for the eight-year period directly and indirectly under the control of the engineering colleges.

The graphs *A* to *J* inclusive therefore show the relation of the various requirements by groups, from the standpoint of the four-year high school period, the four-year college period, and in combination, the entire period of eight years. For convenience different scales are used for the individual items and for the totals.

FIRST DEGREE IN CIVIL ENGINEERING

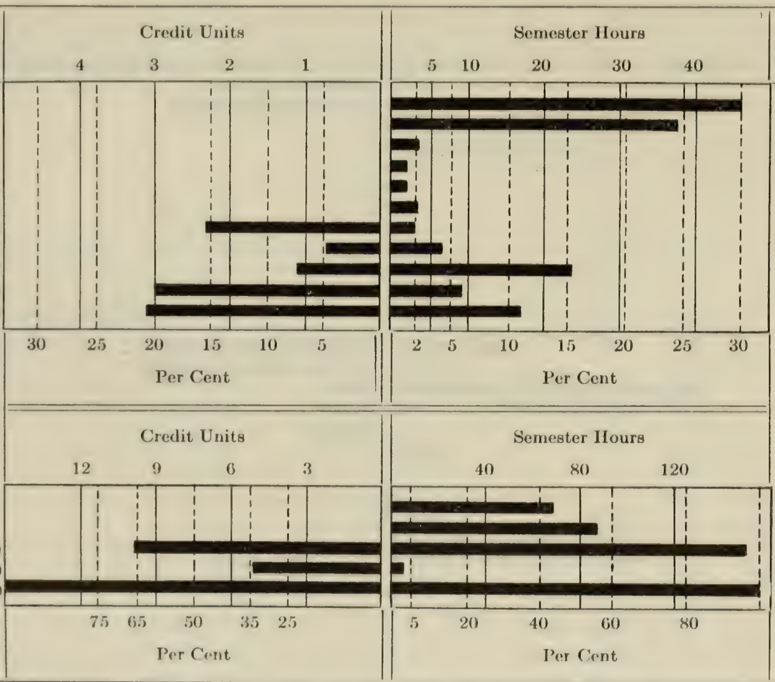


Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		30.0	44.4	Civil Engineering	15.0
		21.4	31.6	Other Engineering	10.7
*	*	4.4	6.6	Engineering Electives	*
*	*	0.8	1.2	Non-Engineering Electives	*
0.0	0.0	0.1	0.2	Miscellaneous	0.0
0.0	0.0	4.5	6.7	Phys. and Mil. Training	2.3
0.9	6.0	1.6	2.3	Foreign Language	3.8
0.8	5.3	2.8	4.2	Social Science	4.1
0.8	5.3	15.5	23.0	Physical Science	10.4
3.0	20.0	6.2	9.2	English	13.1
2.9	19.3	12.4	18.4	Mathematics	15.9
*	*	44.2	65.4	Total Non-Engineering	*
*	*	55.8	82.6	Total Engineering	*
8.4	56.0	94.8	140.2	Total Prescribed	75.4
6.6	44.0	5.2	7.8	Total Electives	24.6
15.0	100.0	100.0	148.0	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH A. Analysis of Average Requirements for Entrance and for Graduation, Civil Engineering Curricula of 55 Public Institutions.

FIRST DEGREE IN CIVIL ENGINEERING

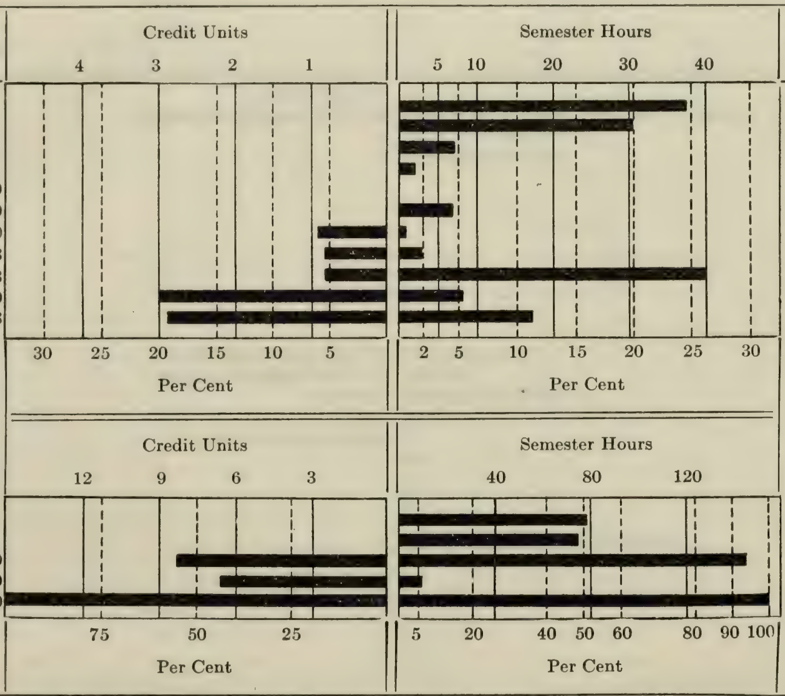


Entrance Requirements Units	Entrance Requirements Per Cent	Graduation Requirements Per Cent	Graduation Requirements Units	Subject Group	Per Cent 8-Yr. Total
		29.7	46.2	Civil Engineering	14.9
		24.1	37.5	Other Engineering	12.0
*	*	2.3	3.6	Engineering Electives	*
*	*	1.3	2.0	Non-Engineering Electives	*
0.0	0.0	1.3	2.0	Miscellaneous	0.7
0.0	0.0	2.2	3.5	Phys. and Mil. Training	1.1
2.3	15.3	2.1	3.2	Foreign Language	8.7
0.7	4.7	4.3	6.7	Social Science	4.5
1.1	7.3	15.2	23.7	Physical Science	11.3
3.0	20.0	6.2	9.6	English	13.1
3.1	20.6	11.0	17.1	Mathematics	15.8
*	*	44.0	68.3	Total Non-Engineering	*
*	*	56.0	87.3	Total Engineering	*
9.9	66.0	96.3	149.8	Total Prescribed	81.2
5.1	34.0	3.7	5.8	Total Elective	18.8
15.0	100.0	100.0	155.6	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH B. Analysis of Average Requirements for Entrance and for Graduation, Civil Engineering Curricula of 28 Private Institutions.

First Degree in Mining Engineering



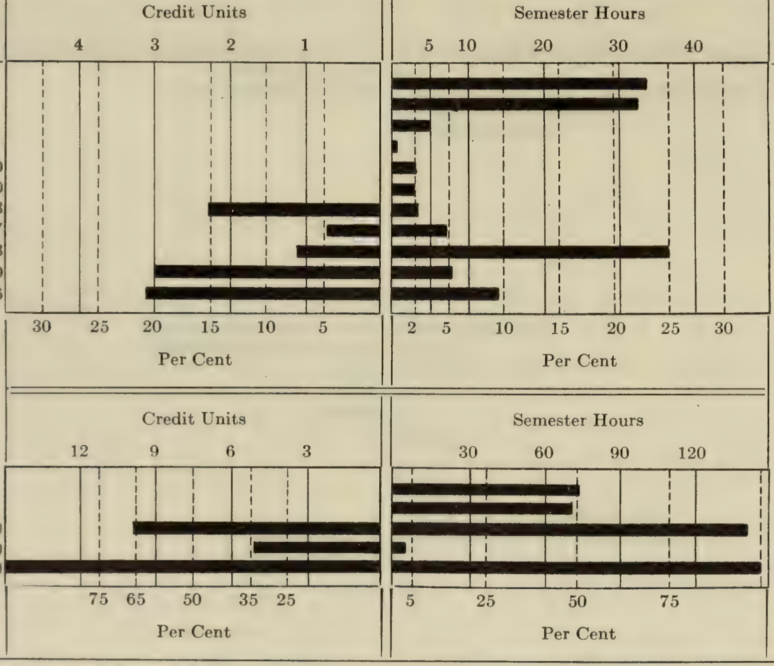
Entrance Requirements: Units	Entrance Requirements: Per Cent	Graduation Requirements: Per Cent	Graduation Requirements: Units	Subject Group	Per Cent 8-Yr. Total
		24.4	37.5	Mining Engineering	12.2
		19.7	30.4	Other Engineering	9.9
*	*	4.7	7.2	Engineering Electives	*
*	*	1.4	2.1	Non-Engineering Electives	*
0.0	0.0	0.0	0.0	Miscellaneous	0.0
0.0	0.0	4.5	7.0	Phys. and Mil. Training	2.3
0.9	6.0	0.6	1.0	Foreign Language	3.3
0.8	5.3	2.1	3.2	Social Science	3.7
0.8	5.3	26.0	40.0	Physical Science	15.7
3.0	20.0	5.2	8.0	English	12.6
2.9	19.3	11.4	17.6	Mathematics	15.4
*	*	51.3	78.8	Total Non-Engineering	*
*	*	48.7	75.0	Total Engineering	*
8.4	56.0	94.1	144.7	Total Prescribed	75.0
6.6	44.0	6.0	9.2	Total Elective	25.0
15.0	100.0	100.0	153.9	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

Graph C. Analysis of Average Requirements for Entrance and for Graduation, Mining Engineering Curricula of 16 Public Institutions.

FIRST DEGREE IN MINING ENGINEERING

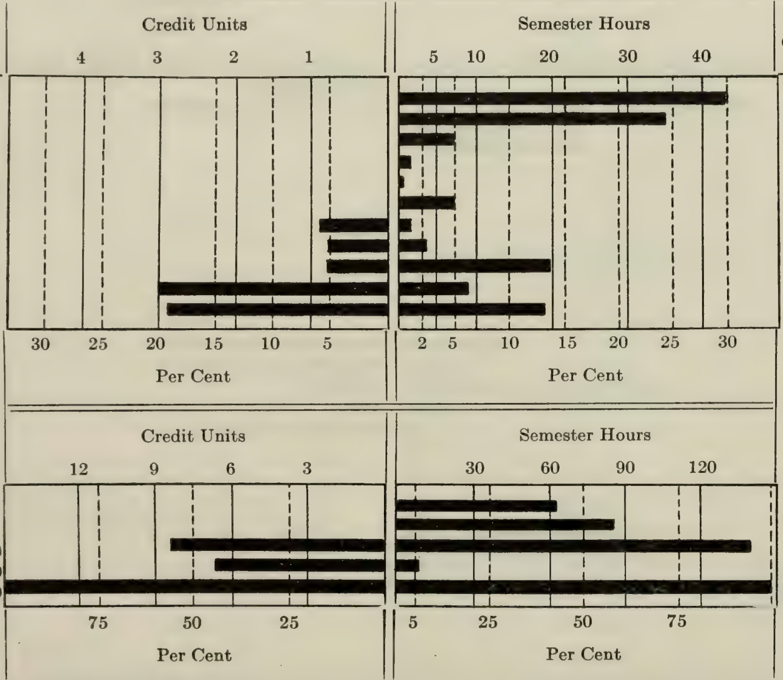
Entrance Requirements: Units	Entrance Requirements: Per Cent	Graduation Requirements: Per Cent	Graduation Requirements: Units	Subject Group	Per Cent 8-Yr. Total
		22.9	33.4	Mining Engineering	11.5
		22.4	32.6	Other Engineering	11.2
*	*	3.5	5.1	Engineering Electives	*
*	*	0.2	0.3	Non-Engineering Electives	*
0.0	0.0	2.0	2.9	Miscellaneous	1.0
0.0	0.0	1.9	2.8	Phys. and Mil. Training	1.0
2.3	15.3	2.2	3.2	Foreign Language	8.8
0.7	4.7	4.9	7.2	Social Science	4.8
1.1	7.3	25.0	36.4	Physical Science	16.2
3.0	20.0	5.3	7.8	English	12.7
3.1	20.6	9.6	14.0	Mathematics	15.1
*	*	51.2	74.6	Total Non-Engineering	*
*	*	48.8	71.2	Total Engineering	*
9.9	66.0	96.3	140.3	Total Prescribed	81.2
5.1	34.0	3.7	5.5	Total Elective	18.8
15.0	100.0	100.0	145.8	Grand Total	100.0



* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH D. Analysis of Average Requirements for Entrance and for Graduation, Mining Engineering Curricula of 9 Private Institutions.

FIRST DEGREE IN MECHANICAL ENGINEERING



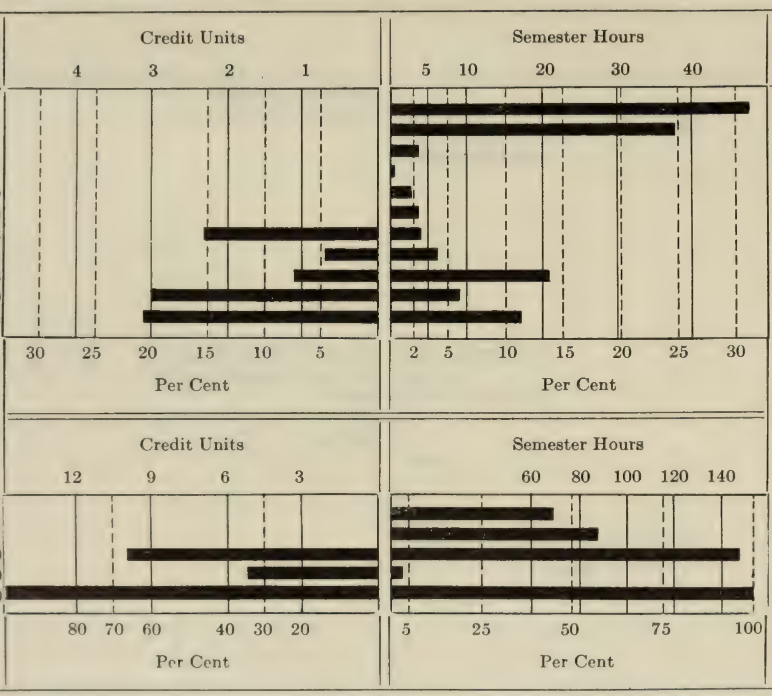
Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		29.1	43.2	Mechanical Engineering	14.6
		23.6	35.0	Other Engineering	11.8
*	*	4.7	7.0	Engineering Electives	*
*	*	0.9	1.4	Non-Engineering Electives	*
0.0	0.0	0.1	0.2	Miscellaneous	0.1
0.0	0.0	4.8	7.1	Phys. and Mil. Training	2.4
0.9	6.0	0.9	1.4	Foreign Language	3.5
0.8	5.3	3.2	4.7	Social Science	4.2
0.8	5.3	13.6	20.1	Physical Science	9.4
3.0	20.0	6.2	9.2	English	13.1
2.9	19.3	12.5	18.6	Mathematics	15.9
*	*	42.4	63.0	Total Non-Engineering	*
*	*	57.6	85.1	Total Engineering	*
8.4	56.0	94.2	139.6	Total Prescribed	75.1
6.6	44.0	5.8	8.6	Total Elective	24.9
15.0	100.0	100.0	148.2	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH E. Analysis of Average Requirements for Entrance and for Graduation, Mechanical Engineering Curricula of 54 Public Institutions.

FIRST DEGREE IN MECHANICAL ENGINEERING

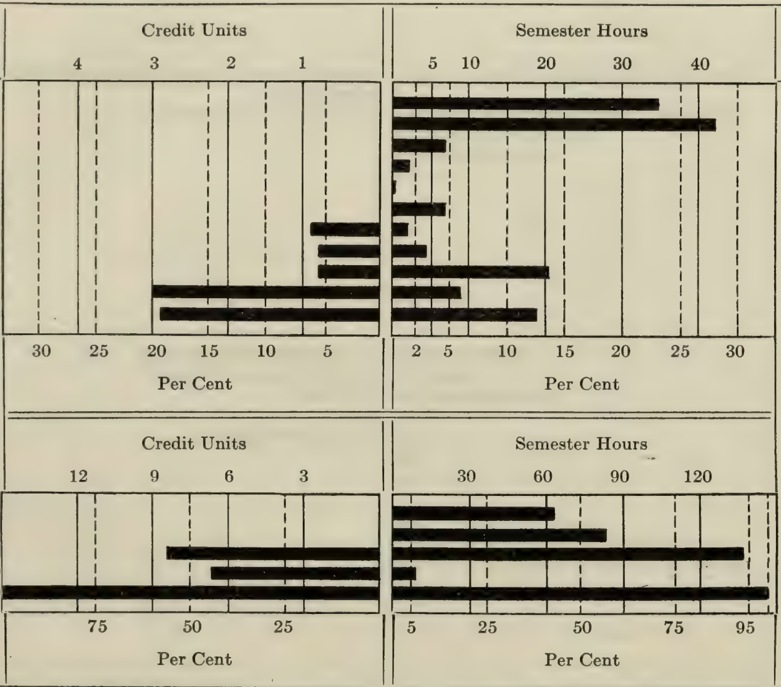
Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		30.9	47.5	Mechanical Engineering	15.5
		24.4	37.5	Other Engineering	12.2
*	*	2.7	4.1	Engineering Electives	*
*	*	0.3	0.5	Non-Engineering Electives	*
0.0	0.0	2.0	3.1	Miscellaneous	1.0
0.0	0.0	2.5	3.8	Phys. and Mil. Training	1.2
2.3	15.3	2.5	3.9	Foreign Language	8.9
0.7	4.7	4.0	6.1	Social Science	4.3
1.1	7.3	13.7	21.0	Physical Science	10.5
3.0	20.0	6.0	9.3	English	13.0
3.1	20.6	11.0	16.9	Mathematics	15.8
*	*	42.0	64.6	Total Non-Engineering	*
*	*	58.0	89.2	Total Engineering	*
9.9	66.0	96.8	148.9	Total Prescribed	81.4
5.1	34.0	3.2	4.9	Total Elective	18.6
15.0	100.0	100.0	153.8	Grand Total	100.0



* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH F. Analysis of Average Requirements for Entrance and for Graduation, Mechanical Engineering Curricula of 22 Private Institutions.

FIRST DEGREE IN ELECTRICAL ENGINEERING

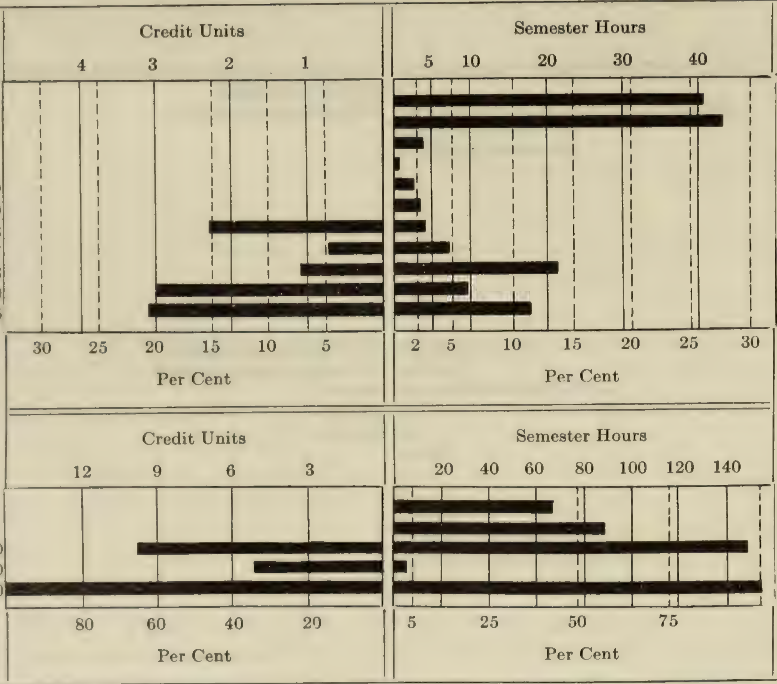


Entrance Requirements Units	Entrance Requirements Per Cent	Graduation Requirements Per Cent	Graduation Requirements Units	Subject Group	Per Cent 8-Yr. Total
		23.4	34.4	Electrical Engineering	11.7
		28.7	42.1	Other Engineering	14.3
*	*	4.6	6.8	Engineering Electives	*
*	*	1.2	1.8	Non-Engineering Electives	*
0.0	0.0	0.1	0.1	Miscellaneous	0.0
0.0	0.0	4.5	6.6	Phys. and Mil. Training	2.3
0.9	6.0	1.4	2.1	Foreign Language	3.7
0.8	5.3	3.0	4.4	Social Science	4.2
0.8	5.3	14.0	20.6	Physical Science	9.6
3.0	20.0	6.1	8.9	English	13.0
2.9	19.3	12.9	18.9	Mathematics	16.1
*	*	43.3	63.6	Total Non-Engineering	*
*	*	56.7	83.3	Total Engineering	*
8.4	56.0	93.7	137.6	Total Prescribed	74.9
6.6	44.0	6.3	9.3	Total Elective	25.1
15.0	100.0	100.0	146.9	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH G. Analysis of Average Requirements for Entrance and for Graduation, Electrical Engineering Curricula of 55 Public Institutions.

FIRST DEGREE IN ELECTRICAL ENGINEERING



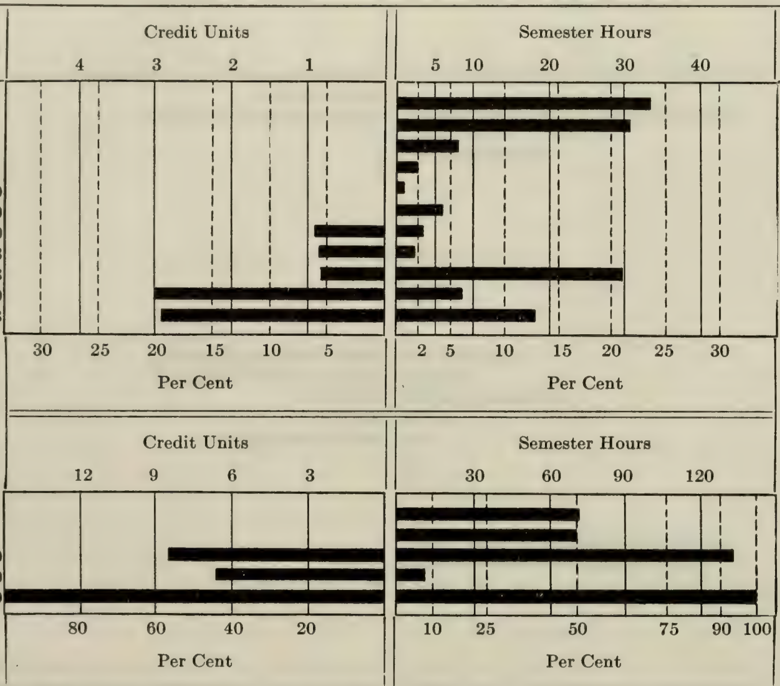
Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		26.2	40.5	Electrical Engineering	13.1
		27.9	43.2	Other Engineering	13.9
*	*	2.7	4.1	Engineering Electives	*
*	*	0.4	0.6	Non-Engineering Electives	*
0.0	0.0	1.6	2.4	Miscellaneous	0.8
0.0	0.0	2.2	3.4	Phys. and Mil. Training*	1.1
2.3	15.3	2.7	4.1	Foreign Language	9.0
0.7	4.7	4.7	7.3	Social Science	4.7
1.1	7.3	14.0	21.6	Physical Science	10.6
3.0	20.0	6.1	9.5	English	13.1
3.1	20.6	11.5	17.8	Mathematics	16.0
*	*	43.2	66.9	Total Non-Engineering	*
*	*	56.8	87.8	Total Engineering	*
9.9	66.0	96.4	149.2	Total Prescribed	81.2
5.1	34.0	3.6	5.6	Total Elective	18.8
15.0	100.0	100.0	154.8	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH H. Analysis of Average Requirements for Entrance and for Graduation, Electrical Engineering Curricula of 23 Private Institutions.

FIRST DEGREE IN CHEMICAL ENGINEERING

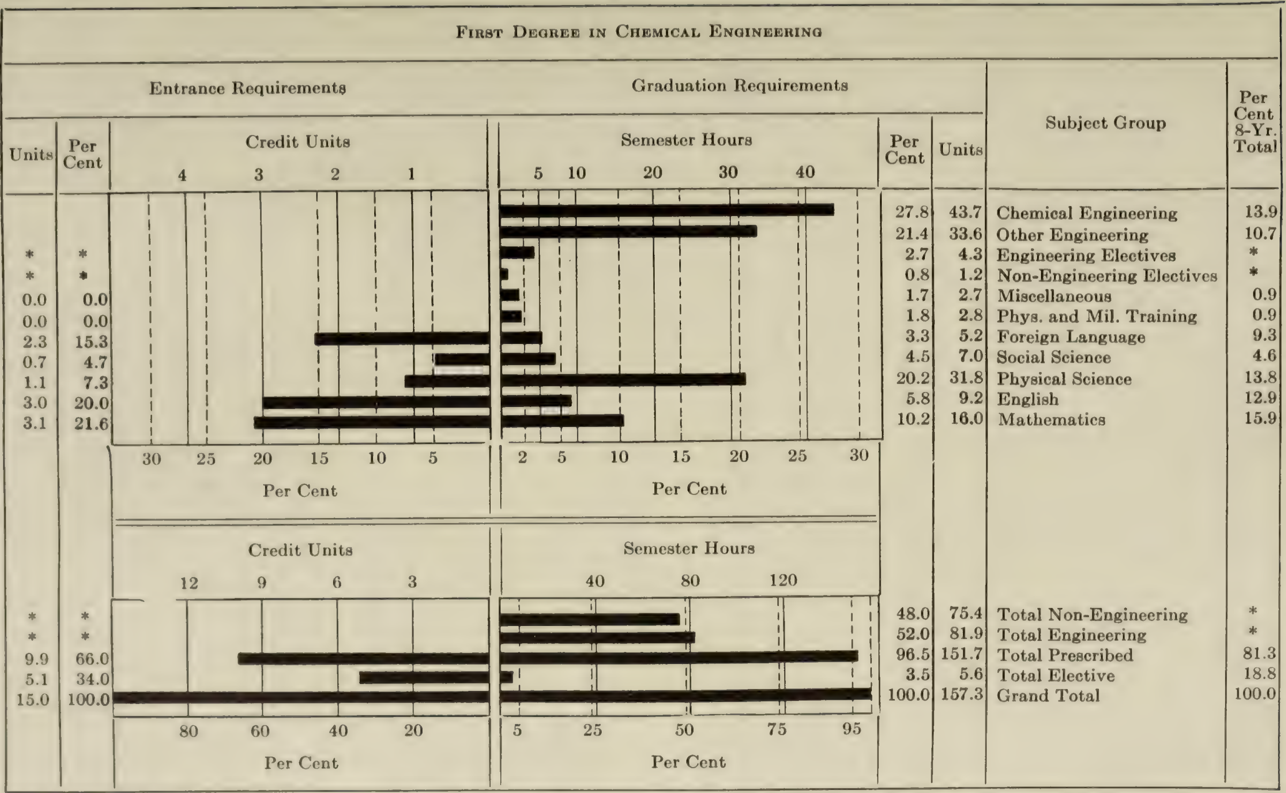
Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		23.2	33.3	Chemical Engineering	11.6
		21.4	30.7	Other Engineering	10.7
*	*	5.4	7.7	Engineering Electives	*
*	*	2.1	3.0	Non-Engineering Electives	*
0.0	0.0	0.6	0.8	Miscellaneous	0.3
0.0	0.0	4.1	5.9	Phys. and Mil. Training	2.1
0.9	6.0	2.5	3.6	Foreign Language	4.3
0.8	5.3	1.7	2.5	Social Science	3.5
0.8	5.3	20.8	29.9	Physical Science	13.1
3.0	20.0	5.8	8.4	English	12.9
2.9	19.3	12.6	18.2	Mathematics	16.0
*	*	50.2	72.2	Total Non-Engineering	*
*	*	49.8	71.4	Total Engineering	*
8.4	56.0	92.5	132.9	Total Prescribed	74.3
6.6	44.0	7.5	10.7	Total Elective	25.7
15.0	100.0	100.0	143.6	Grand Total	100.0



* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH I. Analysis of Average Requirements for Entrance and for Graduation, Chemical Engineering Curricula of 35 Public Institutions.

FIRST DEGREE IN CHEMICAL ENGINEERING



Entrance Requirements		Graduation Requirements			
Units	Per Cent	Per Cent	Units	Subject Group	Per Cent 8-Yr. Total
		27.8	43.7	Chemical Engineering	13.9
		21.4	33.6	Other Engineering	10.7
*	*	2.7	4.3	Engineering Electives	*
*	*	0.8	1.2	Non-Engineering Electives	*
0.0	0.0	1.7	2.7	Miscellaneous	0.9
0.0	0.0	1.8	2.8	Phys. and Mil. Training	0.9
2.3	15.3	3.3	5.2	Foreign Language	9.3
0.7	4.7	4.5	7.0	Social Science	4.6
1.1	7.3	20.2	31.8	Physical Science	13.8
3.0	20.0	5.8	9.2	English	12.9
3.1	21.6	10.2	16.0	Mathematics	15.9
*	*	48.0	75.4	Total Non-Engineering	*
*	*	52.0	81.9	Total Engineering	*
9.9	66.0	96.5	151.7	Total Prescribed	81.3
5.1	34.0	3.5	5.6	Total Elective	18.8
15.0	100.0	100.0	157.3	Grand Total	100.0

* Denotes that the value is indeterminate, since elective entrance credits can not be separated.

GRAPH J. Analysis of Average Requirements for Entrance and for Graduation, Chemical Engineering Curricula of 20 Private Institutions.

PART II. COMPARATIVE SUMMARY AND ANALYSIS OF GRADUATION REQUIREMENTS IN THE FIVE PRINCIPAL ENGINEERING CURRICULA

Relations Shown.—In order to bring out the points of similarity and of difference between the several curricula examined, certain items from the detailed analyses of graduation requirements given in Part IV have been combined in Table I, entitled "Synthesis of Quantitative Standards of Principal Engineering Curricula," and are shown in graphic form in Figs. 1 to 5 inclusive. As a simple means of indicating both the tendency to adhere to a norm and the extent of the variations found, the respective ranges of the lowest fifth, the middle three-fifths and the highest fifth of the cases included, are indicated in the table and the diagrams.

Similarity of Total Requirements.—It is plain from Table I and from Fig. 1 that both the median requirements and the range of the middle three-fifths of the cases are strikingly alike for the five curricula. These requirements are consistently large in comparison with undergraduate college requirements in other fields and seem to point to a tendency to make the four-year requirements in engineering approximate in volume to five years on the usual academic scale.

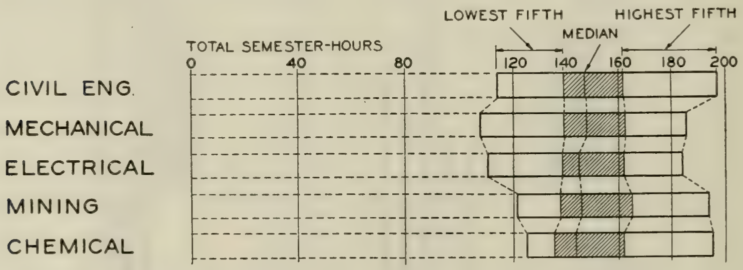


FIG. 1. Range of variation in total semester-hours required for graduation in the five major engineering curricula.

Variations in Group Requirements.—Referring to Fig. 2 and to Table I, it is evident that the mining and chemical engineering curricula are relatively low in the total engineering requirements. This condition is offset, however, by the in-

TABLE I.

SYNTHESIS OF QUANTITATIVE STANDARDS OF PRINCIPAL ENGINEERING CURRICULA.

Based on studies of curricula in 87 institutions.

	Semester-hour Units.											
	Total Semester-Hours.	Prescribed Engineering.		Engineering Electives.	Non-Engineering Subjects.		Mathematics.	Physical Science.	English.	Social Science.	Foreign Language.	Physical and Military Training.
		Principal Branch.	Other Branches.		Required.	Elective.						
MEDIANS												
Civil Engineering	147	43	33	3	64	0	18	22	10	4	0	4
Mining Engineering	146	34	30	6	75	0	18	38	7	4	0	6
Mechanical Engineering	148	44	36	5	63	0	18	20	10	6	0	6
Electrical Engineering	145	34	42	5	64	0	18	20	8.8	5	0	4
Chemical Engineering	144	37	32	5	72.4	0	18	30	8	3	0	4
LOWEST FIFTH												
Civil Engineering	114 to 139	24 to 35	15 to 26	0	39.4 to 54.6	0	11 to 16.6	8.6 to 18	0 to 6	0	0	0
Mining Engineering	121.3 to 138	10.7 to 28.7	11.4 to 25	0	45 to 65	0	9 to 12	24 to 31.3	0 to 6	0	0	0
Mechanical Engineering	108 to 139.6	22 to 34	17 to 30	0	40.7 to 54	0	12 to 16	12 to 16	0 to 6	0	0	0
Electrical Engineering	111 to 139.3	15 to 27	26 to 33	0	40.7 to 54	0	12 to 16	12 to 16	0 to 6	0	0	0
Chemical Engineering	125 to 136	15 to 26	7.3 to 22.3	0	47 to 62	0	9 to 16	12 to 23	0 to 6	0	0	0
					Total.	Elective.						
HIGHEST FIFTH												
Civil Engineering	161.5 to 196.5	54 to 78	41 to 67	12 to 42	78 to 102	10 to 20	20 to 24	28 to 54	12 to 22	8 to 21	6 to 16	9 to 21.3
Mining Engineering	165 to 194	43 to 62	37 to 49	12 to 24	91.7 to 103.5	3 to 16	20 to 23	47 to 55	10 to 20	8 to 14	6 to 11	8 to 16
Mechanical Engineering	162.5 to 184.7	56 to 72	43 to 55	12 to 47	74 to 90	0 to 15	20 to 24	24 to 44	12 to 20	9 to 18	6 to 16	10 to 21.3
Electrical Engineering	162 to 184	48 to 55	50 to 73.3	14 to 81	75 to 88.3	4 to 24	21 to 28	24 to 44	12 to 16	9 to 18	8 to 16	8 to 21.3
Chemical Engineering	162 to 195.5	46 to 73.5	42 to 58	4 to 18	84 to 97.3	4 to 18	20 to 24	37.3 to 50	12 to 16	8 to 18	12 to 18	8 to 12

Notes: Geology and mineralogy are included in the item of physical science.

In addition to the above groups miscellaneous non-engineering subjects are required in certain curricula in mechanical, electrical and chemical engineering included in the highest fifth.

The number of cases included under civil engineering is 83; mining engineering, 25; mechanical engineering, 76; electrical engineering 78; and chemical engineering, 55.

clusion of geology and mineralogy in the non-engineering requirements for mining engineers and the large amount of chemistry required of the chemical engineers, as reflected in the higher requirements in physical science in these two curricula. (See Fig. 4.) It may be noted that the electrical engineering curriculum tends to give the largest time allotment to other branches of engineering.

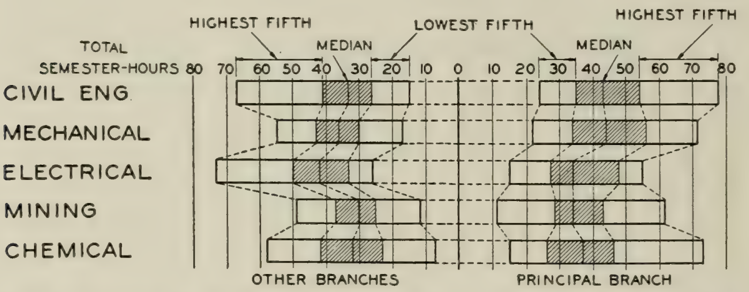


Fig. 2. Range of variation in prescribed requirements in the principal branch of engineering and in other engineering branches.

A comparison of Fig. 2 with Fig. 1 makes it apparent that the total requirements are relatively more closely standardized than the requirements in the engineering subjects proper. Fig. 3 makes it evident that there are wide variations of practice relating to engineering electives, with chemical engineering showing the least variability. Relatively limited provision for elective studies is a general characteristic of engineering curricula.

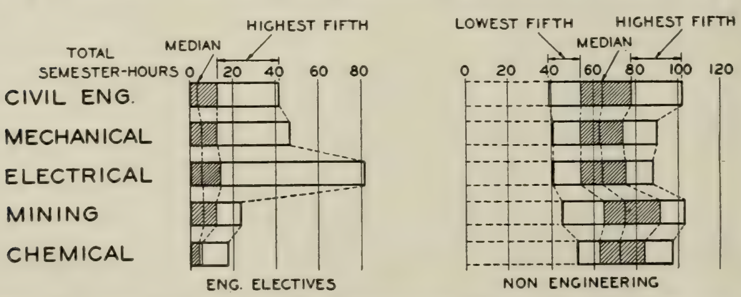


Fig. 3. Range of variation in engineering electives and in non-engineering requirements.

Fig. 4 shows the narrow range of standardization in mathematics. In the civil engineering curriculum the item of physical science is augmented by occasional requirements in astronomy and geology. As previously noted this item is augmented by large requirements in geology and mineralogy in the mining curriculum and by the more extended chemistry in chemical engineering. English and the social sciences indicate only moderate variability.

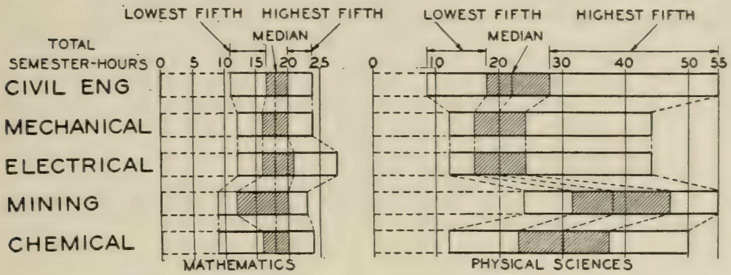


FIG. 4. Range of variation in required mathematics and physical sciences.

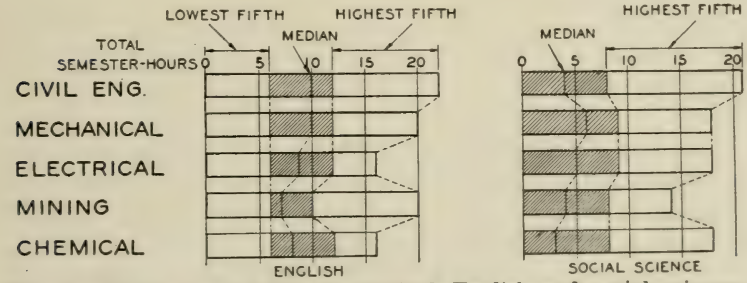


FIG. 5. Range of variation in required English and social sciences.

Differences between Privately and Publicly Controlled Institutions.—It is of some interest to note the indications of differences between the curricula of institutions under private control and those under public control. Differentials in median requirements have been taken from the detailed analyses of Part IV and assembled in Table II for this purpose. It is apparent that the privately controlled institutions have somewhat larger total graduation requirements, especially in prescribed subjects. The public institutions, on the other hand, offer a wider latitude in electives. The private institutions set larger requirements in both non-engineering and engineering subjects, and in both the principal branch of engineering and the collateral branches.

TABLE II.

Differential Requirements in Publicly and Privately Controlled Institutions.

(An excess requirement in privately controlled institutions in indicated by a + sign, and excess in the publicly controlled institutions by a — sign.)

	Curriculum.				
	Civil.	Mechanical.	Electrical.	Mining.	Chemical.
Total requirements	+ 3	+ 5.5	+ 5.5	− 8	+ 10
Total prescribed	+ 9.5	+ 9.5	+ 8	− 2	+ 17.2
Total elective	− 1.5	− 3	− 3	− 2	− 8
Total engineering	+ 4.5	+ 3	0	− 0.5	+ 9.5
Total principal branch	+ 3.5	+ 5	+ 3	− 5	+ 7.5
Total other engineering	+ 5.4	+ 1	− 2.5	+ 1.4	+ 6
Engineering electives	− 4	− 3	− 3	− 1	− 3.4
Mathematics	− 1	− 1	− 2	− 4.7	− 1
Physical science	+ 2	0	+ 0.5	− 4	+ 1.5
Social science	+ 2	+ 1	+ 2	+ 4	+ 4
English	0	− 1	+ 0.3	− 1.5	0
Physical and military	− 4.1	− 4	− 4.6	− 5.5	− 4.7
Mineralogy and geology				+ 4	
Foreign language	0	0	0	0	+ 6

The larger requirements in mathematics in the public institutions are obviously an offset to a lower requirement for entrance. Social sciences are plainly more largely stressed in private institutions, and physical and military training in those under public control. Foreign language appears in the median requirements only in the private institutions and in the chemical engineering curriculum.

Comparison with Agricultural Curricula.—In 1918 Dr. C. D. Jarvis of the United States Bureau of Education made a study of the agricultural curricula in the fifty land-grant colleges of the country. As the classifications of subject groups and other categories are very similar to those used in the present study of engineering fairly accurate comparisons may be made between the two general types of curricula. For this purpose the median requirements in the mechanical engineering curricula of fifty-four state-controlled institutions have been selected. The two institutional lists, comprising fifty cases in agriculture and fifty-four in engineering, are substantially identical. Possibly the most serious criticism that can be directed against these comparisons is the fact that the studies by Dr. Jarvis are six years older than the data used in the engineering study. It seems probable, however, that the changes in the two types of curricula in that period have not been so great as seriously to invalidate the comparisons, with the possible exceptions of the requirements in mathematics and the social sciences.

TABLE III.

Comparison of Curricula in Mechanical Engineering and in Agriculture.

	Per Cent of Total Requirements	
Subject Groups	Mechanical Engineering	Agriculture
Mathematics	12.0	2.4
English	6.7	6.8
Physical science	13.4	24.4
Social science	3.4	4.7
Foreign language	0.0	2.7
Physical and military training	4.7	5.6
Non-technical electives	0 or 4.0	10.7
Technical electives	4.0	
Specific mechanical engineering or agriculture	28.1	31.3
Other engineering or agriculture	23.4	6.2[1] 5.1[2]

[1] Applied sciences.

[2] Agricultural engineering.

PART III. SUMMARY AND ANALYSIS OF ENTRANCE REQUIREMENTS

TABLE IV.

ENTRANCE REQUIREMENTS IN 60 PUBLICLY CONTROLLED INSTITUTIONS. 1924–1925.

Names of Institutions. 1	Total Units. 2	Prescribed Units. 3	Elective Units. 4	Mathematics. 5	English. 6	Physical Science. 7	Social Science. 8	Foreign Language. 9
1. Alabama Polytechnic Institute	15	7	8	3	3	0	1	0
2. University of Alabama	15	6	9	2	3	0	1	0
3. University of Arizona	15	10	5	3	3	1	1	2
4. University of Arkansas	15	6.5	8.5	2.5	3	0	1	0
5. University of California	15	9	6	3	3	2	0	—
6. University of Colorado	15	11	4	3	3	2	1	2
7. Colorado Agricultural College	15	5	10	2	3	0	0	0
8. Colorado School of Mines	15	8	7	3	3	0	2	0
9. Connecticut Agricultural College	14.5	—[1]	—	—	—	—	—	—
10. University of Delaware	15	10	5	3	3	1	1	2
11. University of Florida	16	9	7	4	3	1	1	0
12. University of Georgia	15	9.5	5.5	2.5	3	0	2	2
13. Georgia School of Technology	15	10.5	4.5	3.5	3	1	1	2
14. University of Idaho	15	10	5	3	3	2	2	0
15. University of Illinois	15	7	8	3	3	1	0	0
16. Purdue University	15	8	7	3	3	1	1	0
17. State University of Iowa	15	7	8	3	3	0	1	0
18. Iowa State College	15	7	8	3	3	0	1	0
19. University of Kansas	15	8	7	3	3	2	—	—
20. Kansas State Agricultural College	15	7	8	3	3	1	0	0
21. University of Kentucky	15	7	8	3	3	1	0	0
22. Louisiana State University	16	8.5	7.5	2.5	3	0	1	2
23. University of Maine	14.5	11.5	3	3.5	3	1	1	3 or 4
24. University of Maryland	15	8	7	3	3	1	1	0
25. University of Michigan	15	10	5	3	3	1	1	2
26. Michigan State College	15	7	8	3	3	1	0	0
27. University of Minnesota	15	8	7	3	3	0	0	2
28. University of Mississippi	15	7.5	7.5	2.5	3	0	2	0
29. University of Missouri	15	6	9	1	3	0	0	2

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[1] The dash indicates that specific requirements are not listed and does not necessarily indicate that the subject is not required.

Names of Institutions.	Total Units.	Prescribed Units.	Elective Units.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.
1	2	3	4	5	6	7	8	9
30. Montana State College	15	8	7	3	3	1	1	0
31. University of Nebraska	15	11	4	2.5	3	2	1	2.5
32. University of Nevada	15	9	6	3	3	2	1	0
33. University of New Hampshire	15	8	7	3	3	1	1	0
34. Rutgers University	15	9	6	4	3	0	0	2
35. University of New Mexico	15	10	5	2	3	1	1	2
36. Cornell University	15	11	4	4	3	0	1	3
37. University of North Carolina	15	10	5	3+	3+	1	1	2
38. North Carolina State College	15	8.5	6.5	2.5	3	1	1	1
39. University of North Dakota	15	7	8	3	3	1	0	0
40. Ohio State University	15	9	6	3	3	1	0	2
41. Municipal University of Akron	15	10	5	3	3	1	1	2
42. University of Cincinnati	15	6.5	8.5	2.5	3	—	1	—
43. University of Oklahoma	15	10	5	3	3	1	1	2
44. Oregon Agricultural College	15	5.5	9.5	2.5	3	0	0	0
45. Pennsylvania State College	15	8	7	3	3	1	1	0
46. University of South Carolina	15	11	4	3	3	1	2	2
47. Clemson Agricultural College	15	7.5	7.5	2.5	3	0	2	0
48. University of South Dakota	15	7	8	2	3	1	1	0
49. University of Tennessee	15	9	6	3	3	3	0	0
50. University of Texas	15	8	7	3	3	0	2	0
51. A. and M. College of Texas	15	6	9	3	3	0	0	0
52. University of Utah	15	6	9	2	3	0	1	0
53. University of Vermont	15	10	5	3	3	1	1	2
54. University of Virginia	15	8	7	4	3	0	1	0
55. Virginia Polytechnic Institute	15	8	7	3	3	1	1	0
56. University of Washington	15	8	7	2	3	0	0	3
57. State College of Washington	15	8	7	3	4	1	0	0
58. West Virginia University	15	7	8	3	4	—	—	—
59. University of Wisconsin	15	12[1]	3	3	3	2	2	2
60. University of Wyoming	15	11	4	3	3	1	2	2

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[1] Advised.

TABLE IV—CONTINUED.

ENTRANCE REQUIREMENTS IN 32 PRIVATELY CONTROLLED INSTITUTIONS.

Names of Institutions.	Total Units.	Prescribed Units.	Elective Units.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.
1	2	3	4	5	6	7	8	9
1. Leland Stanford Junior University	15	13.5	1.5	3.5	4	2	1	2
2. California Institute of Technology	15	10	5	4	3	2	1	0
3. Yale University	15	11	4	3	3	1	1	3 or 4
4. George Washington University	15	11	4	4	3	2	0	2
5. Catholic University of America	15	8	7	2	3	0	1	2
6. Howard University	15	5	10	2	3	—	—	—
7. Armour Institute of Technology	15	12.5	2.5	3.5	3	2	1	2
8. University of Notre Dame	15	9	6	2	3	1	1	2
9. Rose Polytechnic Institute	16	9	7	—	—	—	—	—
10. Tulane University of Louisiana	15	9.5	5.5	2.5	3	2	0	2
11. Johns Hopkins University	15	10.5	4.5	2.5	3	0	1	4
12. Harvard University	15	11	4	3	3	1	1	3
13. Tufts College	15	9	6	3	3	0	1	2
14. Massachusetts Institute of Technology	15	13	2	4	3	2	1	4 or 3
15. Worcester Polytechnic Institute	14.5	10.5	4	3.5	3	1	1	2
16. Washington University (St. Louis)	15	6	9	1	1	4	0	2+
17. Stevens Institute of Technology	14.5	11	3.5	4	3	2	1	1
18. Princeton University	15	12	3	4	3	1	0	4
19. Polytechnic Institute of Brooklyn	15	9.5	5.5	3.5	3	1	0	2 or 3
20. New York University	15	10.5	4.5	3.5	3	1	0	3
21. Clarkson College of Technology	15	12	3	3	3	1	1	4
22. Union College	15	9.5	5.5	2.5	3	1	1	2
23. Syracuse University	15	8	7	3	3	0	0	2
24. Rensselaer Polytechnic Institute	15	10	5	3	3	1	1	2
25. Case School of Applied Science	15	10	5	3	3	2	0	2
26. Lehigh University	15	9.5	5.5	3.5	3	0	1	2
27. Lafayette College	15	9.5	5.5	3.5	3	1	0	2
28. Bucknell University	15	9.5	5.5	2.5	3	1	1	2
29. University of Pennsylvania	15	10.5	4.5	3.5	3	1	1	2
30. Swarthmore College	15	9.5	5.5	3.5	3	0	1	2
31. Carnegie Institute of Technology	15	9	6	3	3	1	0	2
32. University of Pittsburgh	15	9	6	3	3	0	1	2

Total Entrance Requirements.—Of the ninety-two institutions of our list eighty-five require a total of fifteen high school units for admission to the regular four year courses of study. The following named institutions prescribe fourteen and one-half units for entrance: Connecticut Agricultural College, University of Maine, Worcester Polytechnic Institute, and Stevens Institute of Technology; sixteen units are prescribed for entrance by the University of Florida, Louisiana State University, and Rose Polytechnic Institute.

Total Prescribed Entrance Requirements.—The following tables show the principal frequencies or modal tendencies of total prescribed entrance requirements in sixty public and thirty-two private institutions, also minimum, maximum and median figures.

TOTAL PRESCRIBED ENTRANCE UNITS. PRINCIPAL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
10	10	0	7
15	13	2	8
11	6	5	9
8	1	7	9½
12	9	3	10
9	5	4	11

MINIMUM, MAXIMUM, AND MEDIAN PRESCRIBED ENTRANCE UNITS.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum	0 or 5[1] units	0 or 5[1] units	5 units
Maximum	13½ units	12 units	13½ units
Median	9 units	8 units	10 units

Total Elective Entrance Requirements.—The tables following show the principal frequencies or modal tendencies of the total elective entrance requirements in the sixty public and thirty-two private institutions of our list, also minimum, maximum and median figures.

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[1] In one case, Connecticut Agricultural College, the prescribed requirements are not specifically listed.

TOTAL ELECTIVE ENTRANCE UNITS. PRINCIPAL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Elective Units Allowed.
9	5	4	4
12	9	3	5
8	1	7	5½
9	5	4	6
17	14	3	7
10	10	0	8

MINIMUM, MAXIMUM, AND MEDIAN ELECTIVE ENTRANCE UNITS.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum........	0 or 1.5[1]	0 or 3[1]	1.5
Maximum........	10	10	10
Median..........	6	7	5

Entrance Requirements in Mathematics.—The tables following show the principal frequencies or modal tendencies of the prescribed entrance requirements in mathematics, also minimum, maximum and median figures.

ENTRANCE REQUIREMENTS IN MATHEMATICS. PRINCIPAL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
8	4	4	2
13	9	4	2.5
47	38	9	3
11	2	9	3.5
9	4	5	4

MINIMUM, MAXIMUM, AND MEDIAN ENTRANCE REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum........	0 or 1	0 or 1	0 or 1
Maximum........	4	4	4
Median..........	3	3	3

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[1] In one case, Connecticut Agricultural College, the elective requirements are not specified.

Entrance Requirements in English.—The tables following show the principal frequencies or modal tendencies of the prescribed entrance requirements in English, also minimum, maximum and median figures.

ENTRANCE REQUIREMENTS IN ENGLISH. ALL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
2	1[1]	1[1]	0
1	0	1	1
86	57	29	3
3	2	1	4

MINIMUM, MAXIMUM, AND MEDIAN ENTRANCE REQUIREMENTS IN ENGLISH.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum........	0 or 1	0 or 3	0 or 1
Maximum.......	4	4	4
Median..........	3	3	3

Entrance Requirements in Physical Science.—The tables following show the principal frequencies or modal tendencies of the prescribed entrance requirements in physical science, also minimum, maximum and median figures.

ENTRANCE REQUIREMENTS IN PHYSICAL SCIENCE. ALL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
33	24	9	0
42	28	14	1
15	7	8	2
1	1	0	3
1	0	1	4

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[1] Specific subjects are not indicated by Connecticut Agricultural College and Rose Polytechnic Institute.

MINIMUM, MAXIMUM, AND MEDIAN ENTRANCE REQUIREMENTS IN PHYSICAL SCIENCE.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum........	0 or 1	0 or 1	0 or 1
Maximum.......	4	3	4
Median..........	1	1	1

Entrance Requirements in Social Science.—The tables following show the frequencies or modal tendencies of the prescribed entrance requirements in social science, also mimimum, maximum and median figures.

ENTRANCE REQUIREMENTS IN SOCIAL SCIENCE. ALL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
29	18	11	0
53	33	20	1
10	9	1	2

MINIMUM, MAXIMUM, AND MEDIAN ENTRANCE REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum........	0 or 1	0 or 1	0 or 1
Maximum.......	2	2	2
Median..........	1	1	1

Entrance Requirements in Foreign Language.—The tables following show the frequencies or modal tendencies of the prescribed entrance requirements in foreign language, also minimum, maximum and median figures.

ENTRANCE REQUIREMENTS IN FOREIGN LANGUAGE. ALL FREQUENCIES.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Units.
39	36	3	0
2	1	1	1
40	19	21	2
1	1	0	2.5
6	3	3	3
4	0	4	4

MINIMUM, MAXIMUM, AND MEDIAN ENTRANCE REQUIREMENTS IN FOREIGN LANGUAGE.

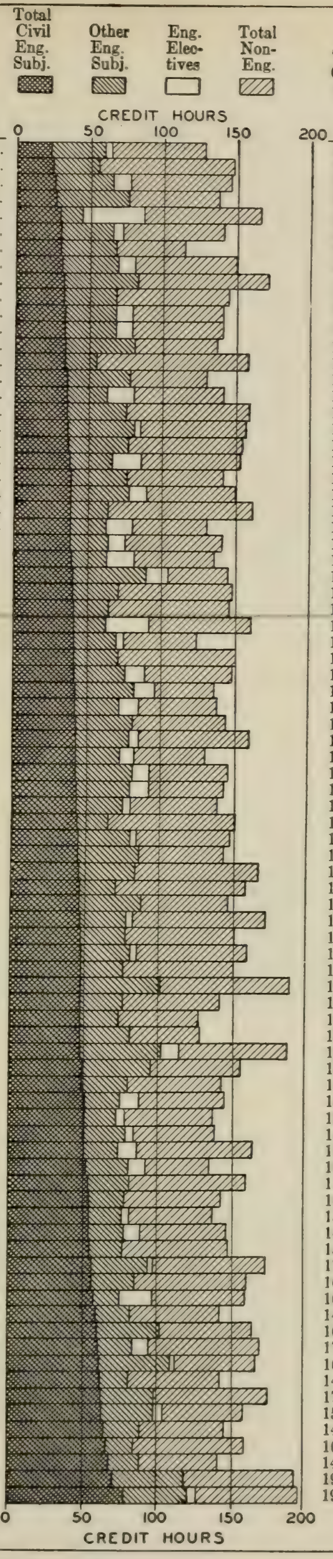
Requirements.	For All Institutions (92).	For Public Institutions (60).	For Private Institutions (32).
Minimum	0 or 1	0 or 1	0 or 1
Maximum	4	3	4
Median	2	0	2

Entrance Requirements in Other Specified Subjects.—Three institutions prescribe drawing in addition to the general academic entrance prescriptions. The University of California prescribes one unit of geometrical drawing. Leland Stanford University and Armour Institute of Technology both prescribe one unit of mechanical drawing.

PART IV. SUMMARY AND ANALYSIS OF GRADUATION REQUIREMENTS

Part IV is divided into five sections, respectively devoted to the curricula in civil, mining, mechanical, electrical and chemical engineering. In each section there are presented: First, a graph showing the total semester-hour requirements of the individual institutions divided into separate items representing the principal engineering subject of the curriculum, other required engineering subjects, elective engineering subjects, and the total of non-engineering subjects, respectively, with the institutions arranged in the ascending order of their requirements in the principal engineering subject; second, a table in two parts which show the detailed requirements by subject groups in the publicly supported and the privately supported institutions respectively; and third, an analysis of the graduation requirements by subject groups with tables showing the distribution of the institutions within the range of requirements, together with maximum, minimum and median values.

A. GRADUATION REQUIREMENTS IN CIVIL ENGINEERING



	Names of Institutions	Total Grad. Req.	Total Civil Eng. Subj.	Other Eng. Subj.	Eng. Elect.	Total Non Eng. Subj.
1	University of Missouri	128	24	37	4	63
2	Swarthmore College	148	25	31	—	92
3	Princeton University	145	26	39	12	68
4	State University of Iowa	137	27	49	0	61
5	Colorado School of Mines	165	30	15	42	78
6	University of Georgia	140	30	36	6	68
7	Harvard University	114	30	39	0	45
8	Rutgers University	150	31	38	12	69
9	California Institute of Technology	171.8	32.6	51.3	0	87.9
10	Clarkson College of Technology	143.9	32.6	35.3	0	76
11	University of Michigan	140	33	35	12	60
12	Mass. Institute of Technology	140	33	35	12	60
13	University of Utah	136.6	34	47.3	0	55.3
14	University of Virginia	158	34	22	0	102
15	University of Mississippi	130	35	43	0	52
16	Yale University	141	35	28	18	60
17	Union College	159	35	40	0	84
18	Carnegie Institute of Technology	155.5	35.6	46.3	3	70.6
19	University of Notre Dame	154	36	41	0	77
20	University of Alabama	153	37	30	20	66
21	University of Florida	141	38	38	0	65
22	University of North Dakota	150	38	39	12	61
23	Clemson Agricultural College	161.5	38	26.5	0	97
24	University of Wyoming	130.6	38	24.6	18	50
25	Lafayette College	142	38	27	12	65
26	Michigan State College	136	38.6	24.6	18.7	54
27	Cornell University	145	39	51	15	40
28	Bucknell University	149	39	32	—	78
29	North Carolina State College	146	39.3	24	0	82.6
30	Colorado Agricultural College	160.6	40	23.6	29	68
31	University of Nebraska	125	40	31	5	49
32	Virginia Polytechnic Institute	151.9	40.6	31.3	0	80
33	University of Arizona	149	41	35	13	60
34	University of Minnesota	136	41.3	41.3	14	39.4
35	Oregon Agricultural College	138.2	41.6	31.3	13.3	52
36	University of New Mexico	144	42	39	0	63
37	University of Tennessee	162	42	36	6	78
38	University of Washington	130.6	42	30.6	10	48
39	University of Wisconsin	146	42	40	11	53
40	University of California	144	43	37	14	50
41	University of Kansas	139	43	32	5	59
42	University of Maryland	152	44	22	(2)*	86
43	West Virginia University	148	45	36	3	64
44	Rose Polytechnic Institute	143	45	42	0	56
45	Lehigh University	168.5	45.5	38	0	85
46	Georgia School of Technology	159.3	46	26	0	87.3
47	University of Oklahoma	147	46	42	0	59
48	Purdue University	174.2	46.3	32.6	4	91.3
49	University of Nevada	152	47	32	(14)*	73
50	Pennsylvania State College	161	47	35	4	75
51	University of Maine	151.5	47.5	30	(4)*	74
52	University of Kentucky	191.1	47.8	54	0	89.3
53	Kansas State Agricultural College	142	48	30	0	64
54	University of Texas	128	48	26	0	54
55	Leland Stanford University	129.1	48	34.6	0	46.5
56	New York University	188	48	55	(12)	73
57	Tulane University of Louisiana	157	50	47	0	60
58	Johns Hopkins University	143	50	31	—	62
59	University of Idaho	147	52	24	14	57
60	Iowa State College	139.3	52	22	6	59.3
61	George Washington University	140	52	28	6	54
62	Case School of Applied Science	167	52	23	13	79
63	University of Arkansas	135.8	52.6	29.3	11.3	42.6
64	University of Delaware	162.5	53.5	29	0	80
65	University of Illinois	145	54	24	0	67
66	State College of Washington	138	54	23	5+	56
67	Washington University (St. Louis)	149	54	25	12	58
68	University of South Carolina	150	55	24	0	71
69	Polytechnic Institute of Brooklyn	176	56.5	39.5	4	76
70	Howard University	161.6	56.6	30	0	75
71	Alabama Polytechnic Institute	160.7	57.9	18.9	22	61.9
72	Louisiana State University	143.9	58.6	24	0	61.3
73	University of South Dakota	167	59	44	0	64
74	A. & M. College of Texas	171	59.5	25.5	12	74
75	Syracuse University	168	62	48	3	55
76	Montana State College	144	62.6	20.6	0	60.6
77	University of Pittsburgh	177	63	36	0	78
78	Ohio State University	159.5	63.3	35.6	6	54.6
79	Tufts College	147	65	26	—	56
80	University of Vermont	160	66	20	(6)*	74
81	University of Colorado	141.9	68.6	22	0	51.3
82	Catholic University of America	193	71	48	0	74
83	Armour Institute of Technology	196.5	78	43	5	70.5

* Options—not included in Total Graduation Requirements.

GRAPH K. Total Semester-Hour Requirements in Principal Subject Groups, Civil Engineering Curricula.

TABLE V.

CIVIL ENGINEERING CURRICULA, 1924–1925.

Graduation Requirements in 55 Publicly Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Civil Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Alabama Polytechnic Institute	160.7	138.7	22	20	12	18.3	5	0	6.6	0	0	57.9	18.9	22	61.9	98.8
2. University of Alabama	153	133	20	20	4	28	10	0	4	0	0	37	30	20	66	87
3. University of Arizona	149	136	13	19	10	18	0	8	4.5	.5	0	41	35	13	60	89
4. University of Arkansas.*	136	124.6	11.3	12	6	20.6	0	0.	4	0	(11.3)	52.6	29.3	11.3	42.6	93.2
5. University of California	144	128	16	12	**	25	2	0	9	0	2	43	37	14	50	94
6. University of Colorado *	142	142	0	21.3	8.7	18	1.3	0	2	0	0	68.6	22	0	51.3	90.6
7. Colorado Agricultural College	161	132	29	24	6	20	2	0	16	0	0	40	23.6	29	68	92.6
8. Colorado School of Mines	165	123	42	20	6	44	0	0	8	0	—	30	15	42	78	87
9. University of Delaware	162.5	162.5	0	16	12	23	7	6	16	0	0	53.5	29	0	80	82.5
10. University of Florida	141	141	0	16	8	29	3	0	9	0	0	38	38	0	65	76
11. University of Georgia	140	134	6	18	6	32	0	12	—	0	0	30	36	6	68	72
12. Georgia School of Technology	159.3	159.3	0	23.7	15	25	5	12	6.7	0	0	46	26	0	87.4	72
13. University of Idaho	147	133	14	18	9	22	0	0	8	0	(14)	52	24	14	57	90
14. University of Illinois	145	136	9	18	6	20	0	8	6	0	9	54	24	0	67	78
15. Purdue University	174.3	164.3	10	20	12	16	6	10	21.3	0	6	46.3	32.6	4	91.3	82.9
16. State University of Iowa	137	137	0	20	12	21	8	0	0	0	0	27	49	0	61	76
17. Iowa State College.*	147.3	141.3	6	24	8.7	23.3	7.3	0	4	0	0	52	22	6	67.3	80
18. University of Kansas	139	129	10	20	11	20	3	0	0	0	5	43	32	5	59	80
19. Kansas State Agricultural College	142	142	0	18	10	22	8	0	6	0	0	48	30	0	64	78
20. University of Kentucky	191	191	0	25	22	32	3	0	7.3	0	0	47.8	54	0	89.3	101.8
21. Louisiana State University.*	144	144	0	18	12	23.3	0	0	8	0	(2)	58.6	24	0	61.3	82.6
22. University of Maine	151.5	151.5	0	20	12	27	15	0	0	0	0	47.5	30	(4)	74	77.5
23. University of Maryland	152	152	0	20	14	22	8	14	8	0	(6)	44	22	(2)	86	66
24. University of Michigan	140	128	12	18	6	20	0	16*	0	0	*	33	35	12	60	80
25. Michigan State College.*	136	111.3	24.7	16	8	16	(12)	(6)	8	0	6	38.6	24.6	18.7	54	81.9

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Civil Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
26. University of Minnesota.*	136	122	14	16.7	6	16.7	0	0	0	0	(14)	41.3	41.3	14	39.4	96.6
27. University of Mississippi	130	130	0	18	6	22	0	6	0	0	0	35	43	0	52	78
28. University of Missouri	128	124	4	20	12	18	5	0	8	0	0	24	37	4	63	65
29. Montana State College.*	144	144	0	18	10	20.6	4	0	8	0	0	62.6	20.6	0	60.6	83.2
30. University of Nebraska	125	120	5	20	4	16	3	0	4	2	0	40	31	5	49	76
31. University of Nevada	152	138	14	16	6	22	2	0	10	3	14	47	32	(14)	73	79
32. Rutgers University	150	138	12	20	12	16	6	6	9	0	(12)	31	38	12	69	81
33. University of New Mexico	144	144	0	18	9	22	(12 or 16)	12 or 16	2.5	0	0	42	39	0	63.5	81
34. Cornell University	145	130	15	11	6	15	8	0	—	0	(15)	39	51	15	40	105
35. North Carolina State College.*	146	128	18	22.6	12	20	2	0	8	0	18	39.3	24	0	82.6	63.3
36. University of North Dakota	150	138	12	18	10	21	6	0	6	0	0	38	39	12	61	89
37. Ohio State University.*	159.5	153.5	6	20	8	20	0	0	6.6	0	0	63.3	35.6	6	54.6	104.9
38. University of Oklahoma	147	147	0	19	8	21	7	0	4	0	0	46	42	0	59	88
39. Oregon Agricultural College	138	124.7	13.3	16	8	14	4	0	10	0	0	41.6	31.3	13.3	52	86.2
40. Pennsylvania State College	161	157	4	16	10	19	12	8	9	1	0	47	35	4	75	86
41. University of South Carolina	150	150	0	12	6	47	0	6	0	0	0	55	24	0	71	79
42. Clemson Agricultural College	161.5	161.5	0	21	16	24	10	0	20	6	0	38	26.5	0	97	64.5
43. University of South Dakota	167	167	0	18	6	25	3	0	12	0	0	59	44	0	64	103
44. University of Tennessee	162	156	6	18	12	28	0	0	20	0	(12)	42	36	6	78	84
45. University of Texas.*	128	128	0	16	14	18	6	0	0	0	0	48	26	0	54	74
46. A. and M. College of Texas	171	159	12	22	16	22	6	0	8	0	(12)	59.5	25.5	12	74	97
47. University of Utah.*	136.6	131.3	5.3	16.6	6	22	3.3	0	2	0	5.3	34	47.3	0	55.2	81.3
48. University of Vermont	166	160	6	24	8	26	4	0	12	0	0	66	20	6	74	92
49. University of Virginia	158	158	0	18	12	54	18	0	0	0	0	34	22	0	102	56
50. Virginia Polytechnic Institute.*	152	152	0	20	12	22	4	0	21	.9	0	40.6	31.3	0	79.9	71.9
51. University of Washington	130.6	120.6	10	12	2	23.3	4	0	6.6	0	(10)	42	30.6	10	47.9	82.6
52. State College of Washington	138	133	5	16	8	18	7	0	7	0	(5+)	54	23	5+	56	82
53. West Virginia University	148	145	3	16	7	27	10	0	4	0	0	45	36	3	64	84
54. University of Wisconsin	141	138	3	18	10	24	4	0	—	0	3	42	40	(3)	59	82
55. University of Wyoming.*	130.6	112.6	18	18	6	18	0	0	8	0	0	38	24.6	18	50	80.6

* Figures reduced to semester-hours from a term or quarter basis.
** Examination required.
( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

TABLE V.

CIVIL ENGINEERING CURRICULA, 1924–1925—*Continued.*

Graduation Requirements in 28 Privately Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Civil Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Leland Stanford University	129	129	0	13.3	10	8.6	10.6	0	4	0	0	48	34.6	0	46.5	82.6
2. California Institute of Technology	172	170.6	1.3	14	20	30	8	0	14.6	0	1.3	32.6	51.3	0	87.9	83.9
3. Yale University	141	123	18	12	12	20	16	0	0	0	(18)	35	28	18	60	81
4. George Washington University	140	134	6	12	6	24	6	6	0	0	0	52	28	6	54	86
5. Catholic University of America	193	193	0	22	6	25	1	6	0	14	0	71	48	0	74	119
6. Howard University *	161.6	161.6	0	20	10	20	10	0	15	0	0	56.6	30	0	75	86.6
7. Armour Institute of Technology	196.5	191.5	5	18	9	31.5	8	0	0	4	0	78	43	5	70.5	126
8. University of Notre Dame	156	156	0	24	10	28	3	0	0	14	0	36	41	0	79	77
9. Rose Polytechnic Institute	143	143	0	17	8	15	2	10	4	0	0	45	42	0	56	87
10. Tulane University of Louisiana	157	157	0	20	15	20	3	0	0	2	0	50	47	0	60	97
11. Johns Hopkins University	143	143	—	16	10	24	6	6	0	0	0	50	31	—	62	81
12. Harvard University	114	108	6	12	6	15	6	0	0	0	6	30	39	0	45	69
13. Tufts College	147	137	10	15	6	16	6	0	3	0	10	65	26	—	56	91
14. Massachusetts Institute of Technology	140	128	12	18	6	20	0	(16)	0	0	(16)	33	35	12	60	80
15. Washington University (St. Louis)	149	137	12	17	8	23	6	0	4	0	(12)	54	25	12	58	91
16. Princeton University	145	133	12	12	8	20	14	12	2	0	(12)	26	39	12	68	77
17. Polytechnic Institute of Brooklyn	176	166	10	20	13	25	8	0	4	0	6	56.5	39.5	4	76	100
18. New York University	188	176	12	14	16	29	2	—	6	0	6	48	67	(12)	73	115
19. Clarkson College of Technology	134	134	0	22	6	34	0	0	4	0	0	32.6	35.3	0	66	67.9
20. Union College	159	159	0	22	14	19	17	10	2	0	0	35	40	0	84	75
21. Syracuse University	168	165	3	18	8	26	3	0	0	0	0	62	48	3	55	113
22. Case School of Applied Science	167	154	13	18	12	29	2	11	7	0	0	52	23	13	79	88
23. Lehigh University	168.5	168.5	0	15	9	33	6	6	11.7	4.3	0	45.5	38	0	85	83.5
24. Lafayette College	142	130	12	17	6	24	6	0	4	8	(12)	38	27	12	65	77
25. Bucknell University	149	143	6	20	6	32	0	12	0	2	6	39	32	—	78	71
26. Swarthmore College	148	128	20	19	10	24	9	10	—	0	20	25	31	—	92	56
27. Carnegie Institute of Technology	155.6	152.6	3	18	6	21	21	0	4.6	0	0	35.6	46.3	3	70.6	84.9
28. University of Pittsburgh	177	177	0	14	14	28	7	0	8	7	0	63	36	0	78	99

* Figures reduced to semester-hours from a term or quarter basis.

( ) indicates that the electives are not always clearly defined either as to engineering or non-engineering electives.

ANALYSIS OF GRADUATION REQUIREMENTS IN CIVIL ENGINEERING

Total Graduation Requirements.—There are fifty-one distinct cases of total graduation requirements in civil engineering in the list of eighty-three colleges of engineering considered here. These totals vary from 114 to 196.5 semester-hour credits.

The following tables show in terms of semester-hour credits the principal frequencies or modal tendencies of the total graduation requirements in civil engineering in fifty-five public and twenty-eight private institutions, also the minimum, maximum, and median figures.

TOTAL GRADUATION REQUIREMENTS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Graduation Requirements in S. H. Credits.
1	0	1	114
4	3	1	125 to 129
12	11	1	130 to 139.3
29	18	11	140 to 149
15	11	4	150 to 159.3
12	8	4	160 to 169
5	2	3	171 to 177
1	0	1	188
3	1	2	191 to 196.5

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL GRADUATION REQUIREMENTS.

Requirements.	For All Institutions (83).	For Public Institutions (55).	For Private Institutions (28).
Minimum......	114	125	114
Maximum......	196.5	191	196.5
Median........	147	146	149

Total Prescribed Credits.—The following tables show the principal frequencies or modal tendencies in the total prescribed semester-hour credits in civil engineering, also the minimum, maximum, and median figures.

TOTAL PRESCRIBED CREDITS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed S. H. Credits.
1	0	0	108
2	2	0	111.3 to 112
16	12	4	120 to 129
23	17	6	130 to 139
11	8	3	141 to 147
16	11	5	150 to 159
8	4	4	161 to 169
3	0	3	170 to 177
3	1	2	191 to 193

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL PRESCRIBED CREDITS.

Requirements.	For All Institutions (83).	For Public Institutions (55).	For Private Institutions (28).
Minimum......	108	111.3	108
Maximum......	193	191	193
Median........	bet. 137 and 141	138	bet. 143 and 152

Total Elective Credits.—The following tables show the principal frequencies of modal tendencies in the total elective semester-hour credits in civil engineering, also the minimum, maximum, and median figures.

TOTAL ELECTIVE CREDITS, CIVIL ENGINEERING CURRICULA.

Number of Cases (83).	In Public Institutions (55).	In Private Institutions (28).	Number of Elective S. H. Credits.
31	20	11	0
20	13	7	3 to 9
26	17	9	10 to 18
5	4	1	20 to 29
1	1	0	42

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ELECTIVE SEMESTER HOUR CREDITS.

Requirements.	For All Institutions (83).	For Public Institutions (55).	For Private Institutions (28).
Minimum........	0 or 1.3	0 or 3	0 or 1.3
Maximum........	42	42	20
Median..........	6	bet. 5 and 6	bet. 3 and 5

The tables show that 37 per cent of all the schools—36 per cent of the public institutions, and 40 per cent of the private institutions—offer no electives in the civil engineering curriculum.

Requirements in Mathematics.—The following tables show the principal frequencies or modal tendencies for graduation requirements in mathematics, also the minimum, maximum, and median figures.

REQUIREMENTS IN MATHEMATICS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	S. H. Credits Prescribed in Mathematics.
8	4	4	12
10	9	1	16
20	15	5	18
17	13	4	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (83).	For Public Institutions (55).	For Private Institutions (28).
Minimum........	11	11	12
Maximum........	25	25	24
Median..........	18	18	17

Requirements in English.—The following tables show the principal frequencies or modal tendencies for graduation requirements in English, also the minimum, maximum, and median figures.

REQUIREMENTS IN ENGLISH, CIVIL ENGINEERING CURRICULA

Number of Cases.	In Public Institutions.	In Private Institutions.	S. H. Credits Prescribed in English.
1	1	0	0[1]
22	13	9	6
11	7	4	8
11	6	5	10
15	13	2	12

[1] University of California requires an examination in English.

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN ENGLISH.

Requirements.	For All Institutions (83).	For Public Institutions (55).	For Private Institutions (28).
Minimum........	0 or 2	0 or 2	6
Maximum........	22	22	20
Median..........	10	9	9

Requirements in Physical Science.—The following tables show the principal frequencies or modal tendencies, for graduation requirements in physical science, also the minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL SCIENCE, CIVIL ENGINEERING CURRICULA.

Number of Cases (83).	In Public Institutions (55).	In Private Institutions (28).	S. H. Credits Prescribed in Physical Science.
19	15	4	14 to 19
11	6	5	20
9	9	0	22
27	15	12	23 to 29

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL SCIENCE.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum........	8.6	14	8.6
Maximum........	54	54	34
Median..........	22	22	24

Requirements in Social Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in social science, also the minimum, maximum, and median figures.

REQUIREMENTS IN SOCIAL SCIENCE, CIVIL ENGINEERING CURRICULA.

Number of Cases (83).	In Public Institutions (55).	In Private Institutions (28).	S. H. Credits Prescribed in Social Science.
18	15	3	0
27	20	7	1 to 5
12	5	7	6
13	8	5	7 to 9
13	7	6	10 to 21

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum........	0 or 1	0 or 1.3	0 or 1
Maximum........	21	18	21
Median..........	4	4	6

The tables show that twenty-seven per cent of the public and about ten per cent of the private institutions do not prescribe social science.

Requirements in Foreign Language.—The following tables show the principal frequencies or modal tendencies for graduation requirements in foreign language, also minimum, maximum, and median figures.

REQUIREMENTS IN FOREIGN LANGUAGE, CIVIL ENGINEERING CURRICULA.

Number of Cases (83).	Number of Public Institutions (55).	Number of Private Institutions (28).	Semester Hour Credits Prescribed in Foreign Language.
47	29	18	0
8	4	4	6
3	3	0	8
4	1	3	10
1	0	1	11
4	2	2	12
1	1	0	14
1	1	0	16

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN FOREIGN LANGUAGE.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum........	0 or 6	0 or 6	0 or 6
Maximum........	16	16	12
Median..........	0	0	0

The tables show that nearly fifty-three per cent of the public and nearly sixty-four per cent of the private institutions do not prescribe foreign language for graduation in civil engineering.

Requirements in Physical and Military Training, and Hygiene.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical and military training, including hygiene, also minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, CIVIL ENGINEERING CURRICULA.

Number of Cases (83).	Number of Public Institutions (55).	Number of Private Institutions (28).	Semester Hour Credits Prescribed in Physical and Military Training.
24	12	12	0
6	3	3	1 to 3
12	6	6	4
11	10	1	8
16	13	3	9 to 21.3

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, INCLUDING HYGIENE.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum........	0 or 2	0 or 2	0 or 2
Maximum........	21	21	15
Median..........	4	6.6	between 2 or 3

The tables show that nearly twenty-two per cent of the public and 43 per cent of the private institutions do not prescribe in physical or military training, etc.

Requirements in Prescribed Miscellaneous Subjects.—Fourteen of the eighty-three institutions considered in this study prescribe certain subjects for graduation in civil engineering in addition to those already mentioned.

These subjects included to large extent orientation courses, also Bible, religion, and psychology.

Non-Engineering Electives.—Thirty-two institutions of the eighty-three listed allow non-engineering electives as a part of the graduation requirements in civil engineering. The table following shows the most important frequencies, also the median, maximum, and minimum figures for these electives.

NON-ENGINEERING ELECTIVES, CIVIL ENGINEERING CURRICULA.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Principal frequencies....	0 6 12	0 6 12	0 6 12
Minimum..............	0 or 1.3	0 or 2	1.3
Maximum..............	20	18	20
Median................	0	0	0

Total Non-Engineering Subjects.—The following tables show the principal frequencies or modal tendencies, in total non-engineering subjects, also the minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester Hour Credits in Non-Engineering Subjects.
7	5	2	40 to 49
20	15	5	50 to 59.3
25	18	7	60 to 69
18	8	10	71 to 79
9	6	3	80 to 89.3
3	2	1	91 to 97
1	1	0	102

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	40	40	45
Maximum......	102	102	92
Median........	64	60	Between 68 and 70

Total Engineering Subjects.—The following tables show the principal frequencies or modal tendencies in total engineering subjects, also minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester Hour Credits in Engineering Subjects.
2	1	1	51 to 56
6	4	2	63 to 69
18	13	5	72 to 79
36	25	11	80 to 89
12	8	4	90 to 99
5	4	1	100 to 105
4	0	4	113 to 126

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	51	56	51
Maximum......	126	105	126
Median........	82.6	80	Bet. 84 and 85

Specific Subjects in Civil Engineering.—The following tables show the principal frequencies or modal tendencies in specific subjects in civil engineering also minimum, maximum, and median figures. Specific civil engineering subjects include courses in surveying, geodesy, structural design, structures, railway engineering, highway engineering, bridges, masonry, reinforced concrete, sewerage and contracts and specifications; but do not include strength of materials, mechanics of materials, statics, kinetics or hydraulics.

Where the curriculum is specialized from the beginning by options the writer has chosen for this study the so-called structural option.

SPECIFIC SUBJECTS IN CIVIL ENGINEERING, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester Hour Credits in Specific Civil Engineering Subjects.
4	2	2	24 to 27
25	15	10	30 to 39
27	23	4	40 to 48
18	11	7	50 to 59.5
7	4	3	62 to 68.6
2	0	2	71 to 78

MINIMUM, MAXIMUM, AND MEDIAN; SPECIFIC SUBJECTS IN CIVIL ENGINEERING.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	24	24	25
Maximum......	68.6	68.6	78
Median........	43	43	Bet. 45 and 48

Requirements in Engineering Subjects other than Civil Engineering.—The following tables show the principal frequencies or modal tendencies in other engineering subjects, also minimum, maximum, and median figures. These subjects include engineering drawing, drafting, general engineering, mechanical engineering, electrical engineering, mechanics, strength of materials, mechanics of materials, hydraulics, heat engines, descriptive geometry, kinematics, statics and other subjects which are not specific civil engineering subjects.

OTHER ENGINEERING SUBJECTS, CIVIL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester Hour Credits in Other Engineering Subjects.
2	2	0	15 to 18.9
27	21	6	20 to 29.3
35	23	12	30 to 39.5
15	7	8	40 to 49
3	2	1	51 to 54
1	0	1	67

MINIMUM, MAXIMUM, AND MEDIAN; OTHER ENGINEERING SUBJECTS.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	15	15	23
Maximum......	67	54	67
Median........	Bet. 32 and 34	30.6	36

Requirements in Engineering Electives.—The following tables show the principal frequencies or modal tendencies in the engineering electives of civil engineering curricula, also, the minimum, maximum, and median figures.

ENGINEERING ELECTIVES, CIVIL ENGINEERING CURRICULA.

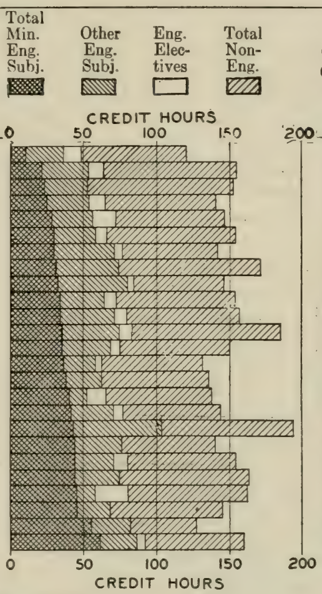
Number of Cases.	In Public Institutions.	In Private Institutions.	Semester Hour Credits in Engineering Electives.
37	21	16	0
20	15	5	1 to 10
22	15	7	10 to 18.7

MINIMUM, MAXIMUM, AND MEDIAN; ENGINEERING ELECTIVES.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	0 or 2	0 or 2	0 or 3
Maximum......	42	42	18
Median........	3	4	0

The tables show that nearly forty per cent of the public institutions and fifty-seven per cent of the private institutions do not allow engineering electives (general options are not included in this statement).

B. GRADUATION REQUIREMENTS IN MINING ENGINEERING



	Names of Institutions	Total Grad. Req.	Total Mining Eng. Subj.	Other Eng. Subj.	Eng. Elect.	Total Non Eng. Subj.
1	Leland Stanford University	121.3	10.7	27.3	13.3	70.0
2	University of Arizona	154	21	33	10	90
3	Virginia Polytechnic Institute	152	24	27.8	—	100.2
4	Yale University	140	25	28	12	75
5	Iowa State College	146	28.7	29.3	16	72
6	University of Alabama	153	30	30.5	7.5	85
7	Princeton University	141	30	42	6	63
8	Lehigh University	172	31	43	0	98
9	West Virginia University	146	32	49	3	62
10	University of Nevada	152	33	31	8	80
11	Notre Dame University	156	33	37	9	77
12	Missouri School of Mines	186	34	39.5	9	103.5
13	Lafayette College	150	34	33	6	77
14	University of Wyoming	131.2	36	23.2	2	70
15	University of Pittsburgh	137	37	25	0	75
16	Oregon Agricultural College	138	40	11.4	13.3	73.3
17	University of California	144	42	30	7	65
18	University of Kentucky	194	42.4	59.9	0	91.7
19	University of Illinois	140	43	32	0	65
20	University of North Dakota	155	43	27	10	75
21	Case School of Applied Science	166	43	31	0	92
22	Colorado School of Mines	165	44	13	24	84
23	University of Kansas	146 +	44 +	23	0	79
24	Harvard University	129	57	27	—	45
25	Ohio State University	160	62	26	6	66

GRAPH L. Total Semester-Hour Requirements in Principal Subject Groups, Mining Engineering Curricula.

TABLE VI.

MINING ENGINEERING, 1924–1925.

Graduation Requirements in 16 Publicly Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Mining and Metallurgy.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.	Geological Subjects.†
1. University of Alabama	153	145.5	7.5	20	4	51	6	0	4	0	—	30	30.5	7.5	85	68	20
2. University of Arizona	154	144	10	17	10	47	3	8	5	0	—	21	33	10	90	64	20
3. University of California	144	137	7	12	**	43	2	0	8	0	—	42	30	7	65	79	21
4. Colorado School of Mines	165	141	24	20	6	50	0	0	8	0	—	44	13	24[1]	84	81	18
5. University of Illinois	140	135	5	13	6	26	0	8	7	0	5	43	32	0	65	75	9
6. Iowa State College.*	146	130	16	19.3	8.7	35.3	(2)	0	4	0	4.7	28.7	29.3	16	72	74	8
7. University of Kansas	146+	138+	8	18	8	40	5	0	—	0	8	44+	23	0	79	67+	15
8. University of Kentucky	194	194	0	23	20	36.5	3	0	9.2	0	0	42.4	59.9	0	91.7	102.3	4
9. Missouri School of Mines	186	177	9	18	12	51.5	6	0	16	0	—	34	39.5	9	103.5	82.5	7
10. University of Nevada	152	144	8	16	6	46	2	0	10	0	—	33	31	8	80	72	18
11. University of North Dakota	155	145	10	18	10	37	4	0	6	0	—	43	27	10	75	80	16
12. Ohio State University.*	160	154	6	20	8	31.3	0	0	6.7	0	—	62	26	6	66	94	11.3
13. Oregon Agricultural College.*	138	124.7	13.3	13.3	6	38	6	0	10	0	—	40	11.4	13.3	73.3	64.7	13.3
14. Virginia Polytechnic Institute.*	152	136	16	20	10	44.7	4	0	5.1	.4	16	24	27.8	—	100.1	51.8	24
15. West Virginia University	146	143	3	16	7	25	10	0	4	0	0	32	49	3	62	84	(5)
16. University of Wyoming.*	131.2	129.2	2	18	6	38	0	0	8	0	0	36	23.2	2	70	61.2	14.6

Graduation Requirements in 9 Privately Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Mining and Metallurgy.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.	Geological Subjects.†
1. Leland Stanford Junior University†	121.3	108	13.3	13.3	4	32.7	14	6	—	—	—	10.7	27.3	13.3	70	51.3	15.3
2. Yale University	140	128	12	12	12	39	12	0	0	0	(6)	25	28	12	75	65	19
3. University of Notre Dame	156	147	9	18	10	35	0	0	0	14	—	33	37	9	77	79	24
4. Harvard University	129	126	3	12	6	24	0	0	0	0	3	57	27	—	45	84	18
5. Princeton University	141	135	6	9	8	24	14	6	2	0	0	30	42	6	63	78	(27)
6. Case School of Applied Science	166	166	0	18	12	40	4	11	7	0	0	43	31	0	92	74	19
7. Lehigh University	172	172	0	15	6	55	6	6	6	4	0	31	43	0	98	74	(24)
8. Lafayette College	150	144	6	17	6	34	8	0	4	8	—	34	33	6	7	73	(12)
9. University of Pittsburgh	137	137	0	12	6	44	7	0	6	0	—	37	25	0	75	62	(16)

* Figures reduced to semester-hours from a term or quarter basis.
** Examination required.
( ) indicates that the election are not always clearly defined either as engineering or non-engineering electives.
† Included under physical science.
[1] Including non-technical.

ANALYSIS OF GRADUATION REQUIREMENTS IN MINING ENGINEERING

Total Graduation Requirements.—There are twenty different cases of total graduation requirements in mining engineering in the list of twenty-five colleges included in this section of the study. These requirements vary from 121.3 to 194 semester-hour credits.

In the tables following are given the modal tendencies, the minimum, maximum, and median figures for total graduation requirements in mining engineering.

TOTAL GRADUATION REQUIREMENTS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Graduation Requirements in Semester-hour Credits.
2	0	2	121.3 and 129
3	2	1	131 to 139
8	6	2	140 to 146
5	4	1	152 to 156
3	2	1	160 to 166
3	2	1	172 to 194

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL GRADUATION REQUIREMENTS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum......	121.3	131.2	121.3
Maximum......	194	194	172
Median........	146	Bet. 146 and 152	141

Total Prescribed Credits.—The following tables show the principal frequencies or modal tendencies in total prescribed semester-hour credits in mining engineering including minimum, maximum, and median figures.

TOTAL PRESCRIBED CREDITS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Semester-hour Credits.
4	2	2	124.7 to 129.2
8	6	2	130 to 137
8	6	2	141 to 147
5	3	2	151 to 194

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL PRESCRIBED CREDITS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum......	108	124.7	108
Maximum......	194	194	172
Median........	141	Bet. 137 and 141	137

Total Elective Credits.—The following tables show the principal frequencies or modal tendencies in total elective semester-hour credits in mining engineering, also minimum, maximum, and median requirements.

TOTAL ELECTIVE CREDITS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Elective Semester-hour Credits.
4	1	3	0
13	9	4	2 to 9
7	5	2	10 to 13.3
1	1	0	24

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ELECTIVE CREDITS.

Requirements.	In All Institutions (25).	In Public Institutions (16).	In Private Institutions (9).
Minimum..............	0 or 2	0 or 2	0 or 3
Maximum..............	24	24	13.3
Median................	8	8	6

These tables show that 16 per cent of all the institutions—6.2 per cent of the public and 33 per cent of the private institutions on our list—do not require elective work.

Requirements in Mathematics.—The following tables show the principal frequencies or modal tendencies for graduation requirements in mathematics, also the minimum, maximum, and median figures.

REQUIREMENTS IN MATHEMATICS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in Mathematics.
1	0	1	9
5	1	3	12
6	4	2	18
4	4	0	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum..............	9	12	9
Maximum..............	23	23	18
Median................	18	18	13.3

Requirements in English.—The following tables show the principal frequencies or modal tendencies for graduation requirements in English, also the minimum, maximum, and median figures.

REQUIREMENTS IN ENGLISH, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in English.
1	1	0	0[1]
2	1	1	4
9	5	4	6
1	1	0	7
3	2	1	8
1	1	0	8.7
4	3	1	10
3	1	2	12
1	1	0	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN ENGLISH.

Requirements	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	0 or 4	0 or 4	4
Maximum........	20	20	12
Median..........	7	Bet. 7 and 8	6

[1] University of California requires an examination in English.

Requirements in Physical Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical science, also the minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL SCIENCE, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hours Prescribed in Physical Science.
4	2	2	24 to 26
10	6	4	31.3 to 39
7	5	2	40 to 47
4	3	1	50 to 55

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL SCIENCE.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	24	25	24
Maximum........	55	51.5	55
Median..........	38	Bet. 38 and 40	35

Requirements in Geology and Mineralogy.—Inasmuch as the physical science requirements for mining engineering include a considerable amount of geology and mineralogy the following tables have been prepared showing the tendencies with respect to requirements in these subjects.

REQUIREMENTS IN GEOLOGY AND MINERALOGY, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hours Prescribed in Geology and Mineralogy.
2	2	0	4 and 5
3	3	0	7 to 9
13	7	6	11.3 to 19
7	4	3	20 to 27

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN GEOLOGY AND MINERALOGY.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	4	4	12
Maximum........	27	24	27
Median..........	16	15	19

Comparing the median requirements of physical science with those of geology, etc., we find that geological subjects comprise 42 per cent of the science subjects required in all the institutions, 40 per cent of the science subjects in the public institutions and 54 per cent of the science subjects in the private institutions.

Requirements in Social Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in social science, also minimum, maximum, and median figures.

REQUIREMENTS IN SOCIAL SCIENCE, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hours Prescribed in Social Science.
6	4	2	0
8	7	1	2 to 4
7	4	3	5 to 8
4	1	3	10 to 14

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	0 or 2	0 or 2	0 or 4
Maximum........	14	10	14
Median..........	4	3	7

The foregoing tables show that 24 per cent of all of the institutions—25 per cent of the public and 22 per cent of the private institutions—do not prescribe social science.

Requirements in Foreign Language.—The following tables show the principal frequencies or modal tendencies for graduation requirements in foreign language, also the minimum, maximum, and median figures.

REQUIREMENTS IN FOREIGN LANGUAGE, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in Foreign Language.
19	14	5	0
3	0	3	6
2	2	0	8
1	0	1	11

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN FOREIGN LANGUAGE.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	0 or 6	0 or 8	0 or 6
Maximum........	11	8	11
Median..........	0	0	0

The tables show that 76 per cent of all the institutions—87 per cent of the public and 55 per cent of the private institutions—do not prescribe foreign language for graduation in mining engineering.

Requirements in Physical and Military Training, and Hygiene.—The following tables show the principal frequencies and modal tendencies in physical and military training, including hygiene, also the minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, INCLUDING HYGIENE; MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in Physical and Military Training.
5	1	4	0
1	0	1	2
4	3	1	4
12	9	3	5 to 9.2
2	2	0	10
1	1	0	16

Minimum, Maximum, and Median; Requirements in Physical and Military Training.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum	0 or 2	0 or 4	0 or 2
Maximum	16	16	7
Median	6	Bet. 7 and 8	2

The foregoing tables show that 20 per cent of the institutions—6 per cent of the public and 44 per cent of the private institutions—do not prescribe physical and military training, etc.

Requirements in Prescribed Miscellaneous Subjects.—Only one of the public institutions and three of the private institutions prescribe work in specific subjects other than those indicated in the preceding paragraphs. These subjects include orientation courses, religion or Bible, and chapel.

Non-Engineering Electives.—Eleven of the public institutions and seven of the private institutions do not specify non-engineering electives as a part of the graduation requirements in mining engineering. In the list of public institutions the specific amount of credits allowed are as follows: 4.7, 5, 8 and 16; in the private, 3 and 6 semester-hours.

Total Non-Engineering Subjects.—The following tables show the principal frequencies or modal tendencies in total non-engineering subjects, also minimum, maximum, and median figures.

Total Requirements in Non-Engineering Subjects, Mining Engineering Curricula.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Non-Engineering Subjects.
1	0	1	45
1	0	1	51.3
6	5	1	62 to 66
8	4	4	70 to 77
3	3	0	80 to 85
4	2	2	90 to 98
2	2	0	100.2 and 103.5

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum	45	62	45
Maximum	103.5	103.5	98
Median	75	Bet. 73.3 and 74	75

Total Engineering Subjects.—The following tables show the principal frequencies or modal tendencies in total engineering subjects, also minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Engineering Subjects.
1	1	0	51.8
7	5	2	61.2 to 68
10	4	6	70 to 79
5	4	1	80 to 84
1	1	0	94
1	1	0	102.3

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum	51.8	51.8	62
Maximum	102.3	102.3	84
Median	74	Bet. 74 and 75	74

Specific Subjects in Mining Engineering.—The tables following show the principal frequencies or modal tendencies in specific subjects in mining engineering, also minimum, maximum, and median figures. The specific subjects in mining engineering include courses in mine surveying, principles of mining, metallurgy, treatment of ores, mining methods, mine ventilation, metal mining, coal mining, mine accounting and other technical subjects in mining and metallurgy. In selecting the curricula for analysis it has been found desirable to follow the general curriculum in mining in cases where no options are offered, but where options are required the metal mining option has been selected.

SPECIFIC SUBJECTS IN MINING ENGINEERING, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Specific Mining Subjects.
1	0	1	10.7
4	3	1	21 to 28.7
10	5	5	30 to 37
8	7	1	40 to 44
1	1	0	62

MINIMUM, MAXIMUM, AND MEDIAN; SPECIFIC SUBJECTS IN MINING ENGINEERING.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	10.7	21	10.7
Maximum.......	62	62	57
Median..........	34	Bet. 36 and 40	33

Requirements in Engineering Subjects other than Mining Engineering.—The following tables show the principal frequencies or modal tendencies in other engineering subjects, also minimum, maximum, and median figures.

OTHER ENGINEERING SUBJECTS, MINING ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Other Engineering Subjects.
2	2	0	11.4 to 13
10	6	4	23 to 29.3
9	6	3	30 to 39.5
3	1	2	42 to 49
1	1	0	59.9

MINIMUM, MAXIMUM, AND MEDIAN; OTHER ENGINEERING SUBJECTS.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	11.4	11.4	25
Maximum........	59.9	59.9	43
Median..........	30	Bet. 29.3 and 30	31

Requirements in Engineering Electives.—The following tables show the principal frequencies or modal tendencies in engineering electives of mining engineering curricula, also the minimum, maximum, and median figures.

ENGINEERING ELECTIVES, MINING ENGINEERING CURRICULA.

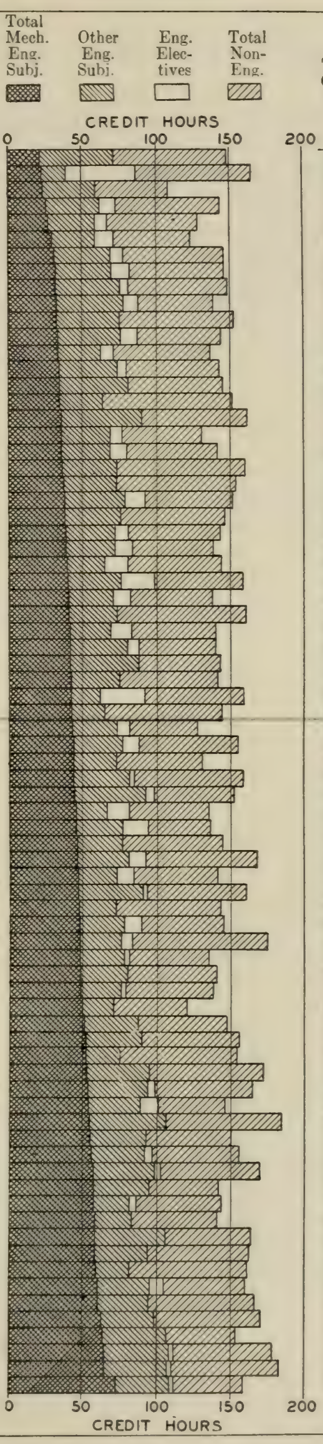
Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Engineering Electives.
8	4	4	0
10	7	3	2 to 9
7	4	3	10 to 16
1	1	0	24

MINIMUM, MAXIMUM, AND MEDIAN; ENGINEERING ELECTIVES.

Requirements.	For All Institutions (25).	For Public Institutions (16).	For Private Institutions (9).
Minimum........	0 or 2	0 or 2	0 or 6
Maximum........	24	24	13.3
Median..........	6	7	6

These tables show that 32 per cent of all the institutions—25 per cent of the public and 44 per cent of those which are private—do not require engineering electives.

C. GRADUATION REQUIREMENTS IN MECHANICAL ENGINEERING.



	Names of Institutions	Total Grad. Req.	Total Mech. Eng. Subj.	Other Eng. Subj.	Eng. Elect.	Total Non Eng. Subj.
1	Univ. of Alabama	148	22	50	0	76
2	Colorado School of Mines	165	23	17	47	78
3	Harvard University	108	24	36	—	48
4	Princeton Universty	145	26	36	12	71
5	University of Missouri	128	27	32	9	60
6	University of Wyoming	124	30	30	14	50
7	Swarthmore College	148	31	39	9	69
8	Rutgers University	148	32	39	12	65
9	Bucknell University	149	32	45	5	67
10	University of Kansas	139.5	32.5	45	10	52
11	Virgina Polytechnic Inst.	151.9	32.6	43.6	0	75.7
12	University of Arizona	143	33	43	11	56
13	Connecticut Agricultural College	137	33	30	9	65
14	University of Florida	143	34	40	6	63
15	State University of Iowa	145	34	47	0	64
16	University of Maryland	151	34	31	(6)*	86
17	University of Virginia	162	35	55	0	72
18	State College of Washington	131	35	35	8	53
19	Lafayette College	142	35	33	12	62
20	Clemson Agricultural College	160.5	36.5	37	0	87
21	University of Delaware	154.5	38	36.5	0	80
22	University of Nevada	152	38	41	14	59
23	University of New Hampshire	146	38	38	0	70
24	University of California	144	39	35	9	61
25	Yale University	138	39	34	12	53
26	Iowa State College	144	39.3	26.7	16	62
27	Alabama Polytechnic Institute	159.7	39.9	36.9	24	58.9
28	Oregon Agricultural College	138.6	40	30.6	12	56
29	University of Tennessee	161	40	34	0	87
30	University of Michigan	140	41	29	15	55
31	George Washington University	140	41	39	8	52
32	Rose Polytechnic Institute	143	41	46	—	56
33	Louisiana State University	142	41.3	34	0	66.7
34	Colorado Agricultural College	160	42	21.3	30.7	66
35	North Carolina State College	144	42	24	0	78
36	University of Washington	127.8	42.6	31.3	9.3	44.6
37	Mississippi A. & M. College	156	44	33.5	12	66.5
38	University of Texas	132	44	30	0	58
39	Notre Dame University	160	44	39	3	74
40	University of Idaho	153	45	48	6	54
41	Michigan State College	135.9	45.3	21.3	15.3	54
42	University of Minnesota	136	45.3	32	18	40.7
43	University of Maine	145	45.5	31.5	0	68
44	A. & M. College of Texas	169	45.5	35.5	12	76
45	University of Arkansas	141.3	46	27.3	12	56
46	Johns Hopkins University	161	46	46	1	68
47	Clarkson College of Technology	143.2	46.6	28.6	0	68
48	Washington University of St. Louis	146	47	32	12	55
49	Purdue University	175.3	47.3	30	8	90
50	University of Utah	136.6	47.3	31.3	4	54
51	Kansas State Agricultural College	141	48	33	0	60
52	Carnegie Institute of Technology	139.6	49	29	3	58.6
53	University of Nebraska	121	50	22	(4)*	49
54	West Virginia University	148	51	37	(6)*	60
55	University of North Dakota	156	52	38	0	66
56	University of Pittsburgh	154	52	24	0	78
57	Catholic University of America	173	52.5	43.5	0	77
58	Pennsylvania State College	166	53	41	5	67
59	University of Wisconsin	146	53	36	12	45
60	University of Kentucky	184.7	54.2	53.2	0	77.3
61	University of Oklahoma	150	55	39	0	56
62	University of Vermont	166	56	36	6	68
63	Massachusetts Institute of Tech.	170.5	57	42.5	4	67
64	University of Colorado	142	57.3	38	0	46.7
65	Montana State College	143.9	57.3	26	2.6	58
66	University of Illinois	141+	58	26	(6)*	57
67	University of South Dakota	164	58	48	0	58
68	Lehigh University	163	58	35	0	70
69	Georgia School of Technology	162.5	58.5	24	0	80
70	Ohio State University	159.2	59.3	37.3	10	52.6
71	Case School of Applied Science	167	60	35	0	72
72	Howard University	171.5	63.3	36.6	0	71.6
73	Cornell University	152	64	44	(4)*	44
74	Armour Institute of Technology	179.5	65	45	3	66.5
75	Polytechnic Institute of Brooklyn	182.5	65	43	4	70.5
76	Syracuse University	159	72	38	2	47

* Options—not included in Total Graduation Requirements.

GRAPH M. Total Semester-Hour Requirements in Principal Subject Groups, Mechanical Engineering Curricula.

TABLE VII.

MECHANICAL ENGINEERING, 1924–1925.

Graduation Requirements in 54 Publicly Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Mechanical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Alabama Polytechnic Institute	159.7	135.7	24	20	12	15.3	5	0	6.6	0	0	39.9	36.9	24	58.9	100.8
2. University of Alabama	148	134	14	20	4	24	10	0	4	0	14	22	50	0	76	72
3. University of Arizona	143	132	11	17	10	16	0	8	0.5	0	0	33	43	11	56	87
4. University of Arkansas.*	141.3	129.3	12	22	6	18	6	0	4	0	0	46	27.3	12	56	85.3
5. University of California	144	120	24	16	**	22	0	0	8	0	15	39	35	9	61	83
6. University of Colorado.*	142	142	0	18	8.6	18	0	0	2	0	0	57.3	38	0	46.7	95.3
7. Colorado Agricultural College	160	129.3	30.7	24	6	20	0	0	16	0	0	42	21.3	30.7	66	94
8. Colorado School of Mines	165	118	47	20	6	44	0	0	8	0	0	23	17	47	78	87
9. Connecticut Agricultural College	137	128	9	15	12	16	12	0	10	0	0	33	30	9	65	72
10. University of Delaware	154.5	154.5	0	24	12	19	7	6	12	0	0	38	36.5	0	80	74.5
11. University of Florida	143	137	6	16	6	26	6	0	9	0	0	34	40	6	63	80
12. Georgia School of Technology	162.5	162.5	0	22.3	15	21	3	12	6.6	0	0	58.5	24	0	80	82.5
13. University of Idaho	153	147	6	18	10	18	0	0	8	0	0	45	48	6	54	99
14. University of Illinois	141+	141	(15)	18	6	16+	0	8	6	0	(9)	58	26	(6)	57	84
15. Purdue University	175.3	161.3	14	20	12	14.7	6	(10)*	21.3	0	6	47.3	30	8	90	85.3
16. State University of Iowa	145	145	0	20	12	19	5	0	8	0	0	34	47	0	64	81
17. Iowa State College.*	144	120	24	19.3	8.7	23.3	6.7	0	4	0	0	39.3	26.7	16	62	82
18. University of Kansas	139.5	129.5	10	20	8	21	3	0	0	0	0	32.5	45	10	52	87.5
19. Kansas State Agricultural College	141	141	0	18	10	18	8	0	6	0	0	48	33	0	60	81
20. University of Kentucky	184.7	184.7	0	23	20	26	1	0	7.3	0	0	54.2	53.2	0	77.3	107.4
21. Louisiana State University.*	142	142	0	20.6	12	24	4	0	6	0	0	41.3	34.6	0	66.6	75.3
22. University of Maine	145	145	0	20	12[1]	23	10	0	—	3	0	45.5	31.5	0	68	77
23. University of Maryland	151	151	(6)	20	14	22	8	14 *	8	0	0	34	31	(6)	86	65
24. University of Michigan	140	125	15	18	6	15	0	16[2]	0	0	0	41	29	15	55	85
25. Michigan State College.*	136	114.6	21.3	16	8	16	(12)*	(6)*	8	0	6	45.3	21.3	15.3	54	82
26. University of Minnesota.*	136	118	18	16.7	6	18	0	0	—	0	—	45.3	32	18	40.7	95.3
27. Mississippi A. and M. College	156	144	12	15	11	24.5	16	0	—	0	(12)	44	33.5	12	66.5	89.5

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Mechanical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
28. University of Missouri	128	119	9	20	12	15	5	0	8	0	0	27	32	9	60	68
29. Montana State College.*	144	141.4	2.6	18	10	18	4	0	8	0	0	57.3	26	2.6	58	86
30. University of Nebraska	121	121	(4)	20	4	16	3	0	4	2	0	50	22	(4)	49	72
31. University of Nevada	152	138	14	16	6	22	2	0	10	3	0	38	41	14	59	93
32. University of New Hampshire	146	134	12	18	10	22	0	0	8	0	12	38	38	0	70	76
33. Rutgers University	148	136	12	20	12	14	4	6	9	0	0	32	39	12	65	83
34. Cornell University	152	152	(4)	11	4	22	7	0	—	0	0	64	44	(4)	44	108
35. North Carolina State College.*	144	132	12	20	12	18	8	0	8	0	12	42	24	0	78	66
36. University of North Dakota	156	156	0	18	14	22	6	0	6	0	0	52	38	0	66	90
37. Ohio State University.*	159.3	149.3	10	20	6	20	0	0	6.6	0	0	59.3	37.3	10	52.6	106.7
38. University of Oklahoma	150	150	0	19	8	18	7	0	4	0	0	55	39	0	56	94
39. Oregon Agricultural College.*	138.6	126.6	12	18	10	12	6	0	10	0	0	40	30.6	12	56	82.6
40. Pennsylvania State College	161	156	5	16	10	15	9	8	9	0	0	53	41[3]	5	67	94
41. Clemson Agricultural College	160.5	160.5	0	21	16	20	10	0	20	0	0	36.5	37	0	87	73.5
42. University of South Dakota	164	164	0	15	3	25	3	0	12	0	0	58	48	0	58	106
43. University of Tennessee	161	155	6	18	12	22	6	0	20	3	6	40	34	0	87	74
44. University of Texas.*	132	132	0	16	12	24	6	0	0	0	0	44	30	0	58	74
45. A. and M. College of Texas	169	157	12	22	16	24	6	0	8	0	0	45.5	35.5	12	76	93
46. University of Utah.*	136.6	130.6	6	20	6	22	2	0	2	0	2	47.3	31.3	4	54	82.6
47. University of Vermont	160	154	6	24	8	20	4	0	12	0	0	56	36	6	58	98
48. University of Virginia	162	162	0	18	12	24	18	[4]	0	0	0	35	55	0	72	90
49. Virginia Polytechnic Institute.*	152	152	0	20	12	18	4	0	21.3	0.4	0	32.6	43.6	0	75.7	76.3
50. University of Washington.*	128	119	9	14	2	20	2	0	6.6	0	0	42.6	31.3	9.3	44.6	83.4
51. State College of Washington	131	121	10	16	8	14	6	0	7	0	2	35	35	8	53	78
52. West Virginia University	148	148	(6)	16	7	23	10	0	4	0	0	51	37	(6)	60	88
53. University of Wisconsin	146	131	15	18	6	18	0	0	—	0	3	53	36	12	45	101
54. University of Wyoming.*	124	110	14	18	6	18	0	0	8	0	0	30	30	14	50	74

* Figures reduced to semester-hours from a term or quarter basis.

** Examination required.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

[1] Includes public speaking.

[2] Includes cultural electives.

[3] Approximate.

[4] Six hours of foreign language may be substituted for social science.

TABLE VII.

Mechanical Engineering, 1924–1925—*Continued.*

Graduation Requirements in 22 Privately Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Semester-Hours.	Total Elective Semester-Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Mechanical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Yale University	138	126	12	12	12	17	12	0	0	0	(12)	39	34	12	53	85
2. George Washington University	140	132	8	12	6	20	8	6	0	0	0	41	39	8	52	88
3. Catholic University of America	173	173	0	22	12	22	1	6	0	14[1]	0	52.5	43.5	0	77	96
4. Howard University.*	171.6	171.6	0	20	10	16.6	10	0	15	0	0	63.3	36.6	0	71.6	100
5. Armour Institute of Technology	179.5	176.5	3	18	9	25.5	10	0	0	4	0	65	45	3	66.5	113
6. University of Notre Dame	160	157	3	23	10	24	3	0	—	14	0	44	39	3	74	86
7. Rose Polytechnic Institute	143	143	—	17	8	15	0	10	4	0	—	41	46	—	56	87
8. Johns Hopkins University	161	160	1	22	10	22	6	8 *	—*	0	—	46	46	1	68	93
9. Harvard University	108	96	12	12	6	12	6	0	0	0	12	24	36	—	48	60
10. Massachusetts Institute of Technology	170.5	166.5	4	12	12	28	3	0	12	0	0	57	42.5	4	67	103.5
11. Washington University (St. Louis)	146	134	12	17	8	20	6	0	4	0	0	47	32	12	55	91
12. Princeton University	145	133	12	12	8	23	14	12	2	0	0	26	36	12	71	74
13. Polytechnic Institute of Brooklyn	182.5	178.5	4	17	13	21.5	14	—	5	0	0	65	43	4	70.5	112
14. Clarkson College of Technology	143.3	143.3	0	18	6	26	14	0	4	0	0	46.6	28.6	0	68	75.3
15. Syracuse University	159	157	2	18	8	18	3	0	0	0	0	72	38	2	47	112
16. Case School of Applied Science	167	167	0	18	12	21	2	12	7	0	0	60	35	0	72	95
17. Lehigh University	163	163	—	17	9	16	6	6	12	4	0	58	35	0	70	93
18. Lafayette College	142	130	12	17	9	18	6	0	4+	8[2]	—	35	33	12	62	80
19. Bucknell University	149	144	5	17	6	30	0	12	0	2	0	32	45	5	67	82
20. Swarthmore College	148	133	15	19	10	22	—	12	0	6	6	31	39	9	69	79
21. Carnegie Institute of Technology	139.6	136.6	3	18	6	18	3	0	4.6	9	0	49	29	3	58.6	81
22. University of Pittsburgh	154	154	0	14	14	26	7	0	10	7	0	52	24	0	78	76

* Figures reduced to semester-hours from a term or quarter basis.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

[1] Philosophy, Religion.

[2] Bible.

ANALYSIS OF GRADUATION REQUIREMENTS IN MECHANICAL ENGINEERING

Total Graduation Requirements.—There are forty-seven different cases of total graduation requirements in mechanical engineering in the list of seventy-six colleges of engineering included in this section of the study. These totals vary from 108 to 184.7 semester-hour credits.

The tables following give in terms of semester-hour credits the principal frequencies or modal tendencies of the "total graduation requirements in mechanical engineering" in fifty-four public and twenty-two private institutions; also the minimum, maximum, and median figures.

TOTAL GRADUATION REQUIREMENTS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Graduation Requirements in Sem.-Hour Credits.
1	0	1	108
4	4	0	120 to 128
10	8	2	130 to 139.6
27	19	8	140 to 149
13	11	2	150 to 159
14	10	4	160 to 169
5	1	4	170 to 179.5
2	1	1	182.5 to 184.7

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL GRADUATION REQUIREMENTS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	108	121	108
Maximum......	184.7	184.7	182.5
Median........	148	146	Bet. 149 and 154

Total Prescribed Credits.—The tables following show the principal frequencies or modal tendencies in the total prescribed semester-hours credits in mechanical engineering; also the minimum, maximum, and median figures.

TOTAL PRESCRIBED CREDITS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Sem.-Hour Credits.
1	0	1	96
6	6	0	110 to 119
11	10	1	120 to 129
17	11	6	130 to 139
14	11	3	140 to 149
13	10	3	150 to 159
9	5	4	160 to 169
4	0	4	170 to 179
1	1	0	184.7

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL PRESCRIBED CREDITS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	96	110	96
Maximum......	184.7	184.7	178.5
Median........	142	Bet. 138 and 141	Bet. 144 and 154

Total Elective Credits.—The tables following show the principal frequencies or modal tendencies in the total elective semester-hour credits in mechanical engineering; also the minimum, maximum, and median figures.

TOTAL ELECTIVE CREDITS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Sem.-Hour Credits.
22	15	7	0
23	14	9	1 to 9
25	19	6	10 to 19
4	4	0	20 to 29
1	1	0	30.7
1	1	0	47

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ELECTIVE CREDITS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	0 or 1	0 or 2.6	0 or 1
Maximum......	47	47	15
Median........	6	6	3

These tables show that 29 per cent of all the schools—27 per cent of the public, and 36 per cent of the private institutions—offer no electives in the mechanical engineering curriculum.

Requirements in Mathematics.—The tables following show the principal frequencies or modal tendencies for graduation requirements in mathematics; also the minimum, maximum, and median figures.

REQUIREMENTS IN MATHEMATICS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-Hour Credits Prescribed in Mathematics.
8	8	0	16
7	1	6	17
18	13	5	18
16	15	1	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	11	11	12
Maximum......	24	24	23
Median........	18	18	17

Requirements in English.—The tables following show the principal frequencies or modal tendencies for graduation requirements in English; also the minimum, maximum, and median figures.

REQUIREMENTS IN ENGLISH, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-Hour Credits Prescribed in English.
1	1	0	0[1]
15	10	5	6
11	7	4	10
18	14	4	12

[1] University of California requires an examination in English.

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN ENGLISH.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum	0 or 2	0 or 2	6
Maximum	20	20	14
Median	10	10	9

Requirements in Physical Science.—The tables following show the principal frequencies or modal tendencies for graduation requirements in physical science; also the minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL SCIENCE, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-Hour Credits Prescribed in Phys. Science.
5	5	0	16
14	11	3	18
7	5	2	20
11	8	3	22
6	5	1	24

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL SCIENCE.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum	12	12	12
Maximum	44	44	30
Median	20	20	20

Requirements in Social Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in social science; also the minimum, maximum, and median figures.

REQUIREMENTS IN SOCIAL SCIENCE, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-Hours Prescribed in Social Science.
16	13	3	0
22	16	6	1 to 5
14	9	5	6
10	8	2	6.7 to 9
6	4	2	10
8	4	4	12 to 18

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	0 or 1	0 or 1	0 or 1
Maximum......	18	18	14
Median........	6	5	6

Requirements in Foreign Language.—The following tables show the principal frequencies or modal tendencies for graduation requirements in foreign language; also the minimum, maximum, and median figures.

REQUIREMENTS IN FOREIGN LANGUAGE, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-Hour Credits Prescribed in Foreign Language.
57	44	13	0
6	3	3	6
4	3	1	8
2	1	1	10
5	1	4	12
1	1	0	14
1	1	0	16

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN FOREIGN LANGUAGE.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	0 or 6	0 or 6	0 or 6
Maximum......	16	16	12
Median........	0	0	0

These tables show that 75 per cent of all the schools—81 per cent of the public and 60 per cent of the private institutions—do not prescribe foreign language for graduation in mechanical engineering.

Requirements in Physical and Military Training, and Hygiene.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical and military training, including hygiene; also the minimum, maximum and median figures.

REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-Hour Credits Prescribed in Physical and Military Training.
19	9	10	0
3	2	1	2
10	6	4	4
14	11	3	5 to 7.3
12	12	0	8
11	7	4	10 to 16
4	4	0	20 to 21.3

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, INCLUDING HYGIENE.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	0 or 2	0 or 2	0 or 2
Maximum......	21.3	21.3	15
Median........	6	7	Bet. 2 and 4

These tables show that 25 per cent of all the schools—nearly 17 per cent of the public and over 45 per cent of the private institutions—do not prescribe physical or military training.

Requirements in Prescribed Miscellaneous Subjects.—Fourteen of the seventy-six institutions considered here prescribe certain subjects for graduation in mechanical engineering in addition to those already mentioned.

These subjects include Bible, religion, psychology, philosophy, and to a considerable extent orientation courses.

Non-Engineering Electives.—Fifteen institutions of the seventy-six listed definitely allow non-engineering electives as a part of the graduation requirements in mechanical engineering. The table below shows the principal frequencies.

NON-ENGINEERING ELECTIVES, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-Hour Credits in Non-Engineering Electives.
61	42	19	0
3	3	—	6
5	3	2	12
7	6	1	Other credits

Total Non-Engineering Subjects.—The following tables show the principal frequencies or modal tendencies in total-non-engineering subject; also the minimum; maximum, and median figures.

TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-Hour Credits in Non-Engineering Subjects.
8	6	2	40 to 49
23	18	5	50 to 59
23	16	7	60 to 69
16	8	8	70 to 79
6	6	0	80 to 90

MINIMUM, MAXIMUM, AND MEDIAN FIGURES; TOTAL NON-ENGINEERING SUBJECTS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	40.7	40.7	47
Maximum......	90	90	78
Median........	63	60	67

Total Engineering Subjects.—The tables below show the principal frequencies or modal tendencies in total engineering subjects; also minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-Hour Credits in Engineering Subjects.
4	3	1	60 to 69
16	12	4	70 to 79
28	21	7	80 to 89
16	11	5	90 to 99
11	6	5	100 to 113

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ENGINEERING SUBJECTS.

Requirements.	For All Institutions (76).	For Public Institutions (54).	For Private Institutions (22).
Minimum......	60	65	60
Maximum......	113	108	113
Median........	85	84	87

Specific Subjects in Mechanical Engineering.—The tables following show the principal frequencies or modal tendencies in specific subjects in mechanical engineering; also minimum, maximum, and median figures. Specific mechanical engineering subjects include courses in mechanical engineering, shop work, thermodynamics, kinematics and machine design, heat engines, mechanics of machinery, power engineering, automotive engineering, industrial management and contracts and specifications; but do not include strength of materials, mechanics of materials, statics, hydraulics, mechanical drawing, descriptive geometry, applied mechanics, etc.

SPECIFIC SUBJECTS IN MECHANICAL ENGINEERING, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-Hour Credits in Specific Mechanical Engineering Subjects.
5	3	2	20 to 29
22	18	4	30 to 39
25	18	7	40 to 49
18	14	4	50 to 59
5	1	4	60 to 69
1	0	1	72

MINIMUM, MAXIMUM, AND MEDIAN; SPECIFIC SUBJECTS IN MECHANICAL ENGINEERING.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	22	22	24
Maximum......	72	64	72
Median........	44	42	47

Requirements in Engineering Subjects other than Mechanical Engineering.—The following tables show the principal frequencies or modal tendencies in other engineering subjects; also minimum, maximum, and median figures.

These subjects include mechanical or engineering drawing, drafting, descriptive geometry, engineering or applied mechanics, mechanics or strength of materials, hydraulics, surveying, civil engineering, electrical engineering, etc.

OTHER ENGINEERING SUBJECTS, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-Hour Credits in Other Engineering Subjects.
1	1	0	17
13	10	3	21 to 29
42	30	12	30 to 39
17	10	7	40 to 49
3	3	0	50 to 55

MINIMUM, MAXIMUM, AND MEDIAN; OTHER ENGINEERING SUBJECTS.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	17	17	24
Maximum......	55	55	46
Median........	36	35	36

Requirements in Engineering Electives.—The tables following show the principal frequencies or modal tendencies in the engineering electives of mechanical engineering curricula; also the minimum, maximum, and median figures.

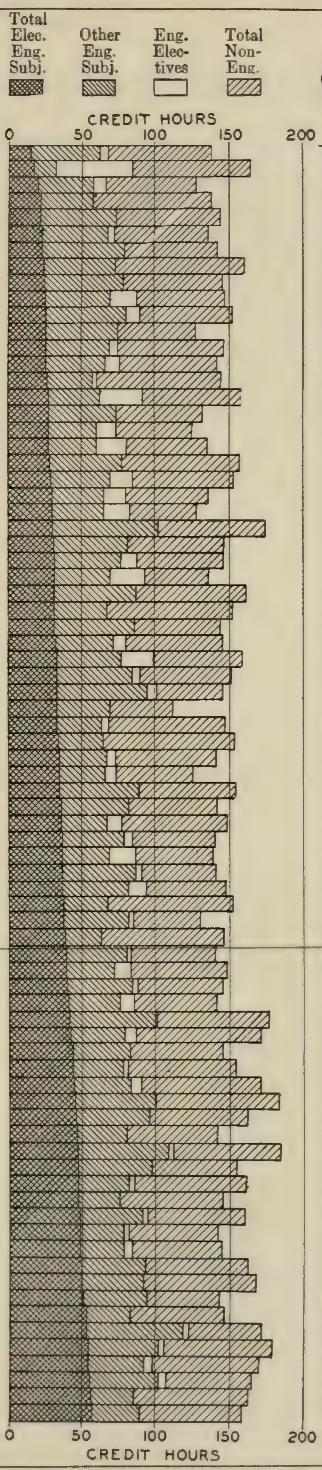
ENGINEERING ELECTIVES, MECHANICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-Hour Credits in Engineering Electives.
27	19	8	0
27	17	10	1 to 9
19	15	4	10 to 19
3	3	0	All other figures

MINIMUM, MAXIMUM, AND MEDIAN; ENGINEERING ELECTIVES.

Requirements.	For All Institutions.	For Public Institutions.	For Private Institutions.
Minimum......	0 or 1	0 or 2.6	0 or 1
Maximum......	47	47	12
Median........	5	6	3

D. GRADUATION REQUIREMENTS IN ELECTRICAL ENGINEERING



	Names of Institutions	Total Grad. Req.	Total Elec. Eng. Subj.	Other Eng. Subj.	Eng. Elect.	Total Non Eng. Subj.
1	University of Tennessee	138.5	15	48.5	6	69
2	Colorado School of Mines	165	17	17	53	78
3	University of Missouri	128	20	39	9	60
4	University of Georgia	138	22	36	0	80
5	University of New Hampshire	144	22	52	0	70
6	University of Utah	135.3	22.6	46	4.4	62
7	University of Florida	142	23	57	0	62
8	Clemson Agricultural College	160.5	24.5	49	0	87
9	University of Louisiana	145.3	24.6	54	0	66.6
10	University of Wisconsin	146	25	45	19	57
11	University of Nevada	152	26	55	10	61
12	Washington State College	128	26	49	(12)*	53
13	Princeton University	147	26	44	6	71
14	Lafayette College	142	26	41	9	66
15	Swarthmore College	144	27	32	2	83
16	Colorado Agricultural College	159.3	28	35.3	30	66
17	University of Texas	132	28	46	0	58
18	University of Wyoming	124.6	28	32.6	14	50
19	Yale University	136	28	34	21	53
20	University of Delaware	157.5	28.5	49	0	80
21	University of Alabama	152	29	41	16	66
22	Michigan State College	136	30	36	16	54
23	University of Washington	128	30	35.3	18	44.7
24	Howard University	175	30	73.3	0	71.7
25	University of Iowa	145	31	50	0	64
26	University of Arizona	145	32	46	11	56
27	University of Minnesota	136	32	38	25.3	40.7
28	University of Virginia	162	32	56	0	74
29	Virginia Polytechnic Institute	152	32	36.4	0	83.6
30	Rose Polytechnic Institute	143	32	55	(6)*	56
31	Iowa State College	143.3	32.6	39.3	9.4	62
32	Alabama Polytechnic Institute	159.1	33	44.2	23	58.9
33	University of Idaho	151	33	51	6	61
34	Cornell University	146	33	63	7	43
35	Harvard University	111	33	36	—	42
36	Union College	148	33	32	6	77
37	Georgia School of Technology	153.1	33.3	31.5	0	88.3
38	University of Maine	140	34	33.5	6.5	66
39	University of Nebraska	125	34	32+	7	52
40	University of North Dakota	154	34	54	0	66
41	Kansas State College	141	35	46	0	60
42	Bucknell University	149	35	32	10	72
43	University of Kansas	139.5	36	43.5	6	54
44	Oregon Agricultural College	139.2	36	32.6	18	52.6
45	George Washington University	140	36	50	4	50
46	Washington University (St. Louis)	148	36	45	12	55
47	University of Maryland	152	37	31	0	84
48	University of Mississippi	130	37	44	3	46
49	North Carolina State College	146	38	26	—	82
50	University of Illinois	140	39	42	33	57
51	Rutgers University	149	39	33	12	65
52	West Virginia University	145	40	45	3	57
53	University of Arkansas	141.9	40.6	35.3	12	54
54	University of South Dakota	176	41	60	0	75
55	Purdue University	171.6	41.3	37.7	9	83.6
56	University of California	144	43	40	(30)*	61
57	University of Pittsburgh	153	43	35	1	74
58	A. & M. College of Texas	172	43.5	39.5	8	81
59	Catholic University of America	183	44	56	0	83
60	Pennsylvania State College	161	45	50	(14)*	66
61	University of Michigan	140	47	34	(14)*	59
62	Armour Institute of Technology	184	47.5	61	3	72.5
63	University of Oklahoma	154	48	50	0	56
64	University of Notre Dame	162	48	35	4	75
65	Clarkson College of Technology	144	48	30	0	66
66	Johns Hopkins University	159	49	44	2	64
67	Carnegie Institute of Technology	142.6	49	32	3	58.6
68	Montana State College	144	49.4	31.3	5.3	58
69	University of Vermont	162	50	44	(6)*	68
70	Case School of Applied Science	168	50	43	0	75
71	University of Colorado	142	50.6	44.7	0	46.7
72	University of New Mexico	145	52	30	0	63
73	Syracuse University	172	52	67	2	51
74	Polytechnic Institute of Brooklyn	178	52.5	48.5	4	72.5
75	Massachusetts Institute of Tech.	169.6	52.5	38.25	6	73
76	Ohio State University	164.6	53.3	46.6	5.3	58.6
77	Lehigh University	162	54	30	—	78
78	University of South Carolina	158	55	33	0	70

* Options—not included in Total Graduation Requirements.

GRAPH N. Total Semester-Hour Requirements in Principal Subject Groups, Electrical Engineering Curricula.

TABLE VIII.

ELECTRICAL ENGINEERING, 1924–1925.

Graduation Requirements in 55 Publicly Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Electrical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Alabama Polytechnic Institute	159.1	136.1	23	20	12	15.3	5	0	6.6	0	0	33	44.2	23	58.9	100.2
2. University of Alabama	152	136	16	25	4	22	10	0	4	1	0	29	41	16	66	86
3. University of Arizona	145	134	11	17	10	16	0	8	4	1	0	32	46	11	56	89
4. University of Arkansas.*	141.9	129.9	12	22	6	18	6	0	4	0	(12)	40.6	35.3	12	54	87.9
5. University of California	144[1]	120	24	12	**	22	0	0	8	0	15	43	40	(30)	61	83
6. University of Colorado.*	142	142	0	18	8.6	18	0	0	2	0	0	50.6	44.7	0	46.7	95.3
7. Colorado Agricultural College	159.3	129.3	30	24	6	20	0	0	16	0	—	28	35.3	30	66	93.3
8. Colorado School of Mines	165	112	53	20	6	44	0	0	8	0	—	17	17	53	78	87
9. University of Delaware	157.5	157.5	0	24	12	19	7	6	12	0	0	28.5	49	0	80	77.5
10. University of Florida	142	142	0	16	8	26	3	0	9	0	0	23	57	0	62	80
11. University of Georgia	138	138	0	24	6	38	0	12	0	0	0	22	36	0	80	58
12. Georgia School of Technology	153.1	153.1	0	23.7	15	22	9	12	6.6	0	0	33.3	31.5	0	88.3	64.8
13. University of Idaho	151	145	6	21	10	22	0	0	8	0	—	33	51	6	61	90
14. University of Illinois	140	129	11	15	6	12	0	8	7	0	8	39	42	3	56	84
15. Purdue University	171.6	162.6	9	20	12	14.3	6	10	21.3	—	—	41.3	37.7	9	83.6	88
16. State University of Iowa	145	145	0	20	12	19	5	0	8	0	0	31	50	80	64	81
17. Iowa State College.*	143.3	133.9	9.4	19.3	8.7	24	6+	0	4	0	—	32.6	39.3	9.4	62	81.3
18. University of Kansas	139.5	133.5	6	20	8	23	3	0	—	0	—	36	43.5	6	54	85.5
19. Kansas State Agricultural College	141	141	0	18	10	18	8	0	6	0	0	35	46	0	60	81
20. Louisiana State University.*	145.3	145.3	0	20.6	12	24	4	0	6	0	0	24.6	54	0	66.6	78.6
21. University of Maine	140	133.5	6.5	20	12	21	13	0	—	0	—	34	33.5	6.5	66	74
22. University of Maryland	152	152	(6)	20	14	22	6+	14	8	0	(6)	37	31	0	84	68
23. University of Michigan	140	140	(14)	18	6	19	—	16	0	—	—	47	34	(14)	59	81
24. Michigan State College.*	136	114	22	16	8	16	—	—	8	—	6	30	36	16	54	82
25. University of Minnesota	136	111.7	25.3	16.7	6	18	—	—	—	—	0	32	38	25.3	40.7	95.3
26. University of Mississippi	130	127	3	18	6	16	0	6	0	0	—	37	44	3	46	84
27. University of Missouri	128	119	9	20	12	15	5	0	8	0	—	20	39	9	60	68
28. Montana State College.*	144	138.7	5.3	18	10	18	4	0	8	—	—	49.4	31.3	5.3	58	86

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Electrical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
29. University of Nebraska	125	118	7	20	4	16	6	0	4	2	—	34	32+	7	52	73
30. University of Nevada	152	142	10	16	6	27	2	0	10	0	—	26	55	10	61	91
31. University of New Hampshire	144	132	12	18	10	22	—	0	8	0	12	22	52	0	70	74
32. Rutgers University	149	137	12	20	12	14	4	6	9	0	—	39	33	12	65	84
33. Cornell University	146	139	7	14	4	21	4	0	—	0	—	33	63	7	43	103
34. University of New Mexico	145	133	12	18	9	22	—	—	—	2	12	52	30	0	63	82
35. North Carolina State College.*	146	122	24	20	12	18	—	—	8	—	24	38	26	—	82	64
36. University of North Dakota	154	154	0	18	14	22	6	0	6	0	0	34	54	0	66	88
37. Ohio State University.*	164.6	158.6	6	20	6	22	4	0	6.6	0	0	53.3	46.6	5.3 to 6	58.6	106
38. University of Oklahoma	154	154	0	19	8	18	7	0	4	0	0	48	50	0	56	98
39. Oregon Agricultural College.*	139.2	121.2	18	16	8	12	6	0	10	.6	—	36	32.6	18	52.6	86.6
40. Pennsylvania State College	161	145	16	16	10	14	9	8	9	0	0	45	50	(14)[2]	66	95
41. University of South Carolina	158	158	0	18	12	25	9	6	0	0	0	55	33	0	70	88
42. Clemson Agricultural College	160.5	160.5	0	21	16	20	10	0	20	0	0	24.5	49	0	87	73.5
43. University of South Dakota	176	176	0	21	6	33	3	0	12	0	0	41	60	0	75	101
44. University of Tennessee	138.5	132.5	6	18	12	19	0	0	20	0	—	15	48.5	6	69	69.5
45. University of Texas.*	132	132	0	12	12	28	6	0	0	0	0	28	46	0	58	74
46. Agricultural and Mechanical College of Texas	172	152	20	22	16	17	6	0	8	0	12	43.5	39.5	8	81	91
47. University of Utah.*	135.3	130.6	4.7	20	6	22	12	0	2	0	—	22.6	46	4.4	62	73.3
48. University of Vermont	162	162	(6)	24	8	20	4	0	12	0	0	50	44	(6)[3]	68	94
49. University of Virginia.*	162	162	0	20	12	24	18	—	0	0	—	32	56	0	74	88
50. Virginia Polytechnic Institute.*	152	152	0	22	12	24	4	0	21+	.4	0	32	36.4	0	83.6	68.4
51. University of Washington.*	128	110	18	14	2	22	0	0	6.7	0	—	30	35.3	18	44.7	83.3
52. State College of Washington	128	116	12	16	8	14	8	0	7	0	—	26	49	(12)	53	75
53. West Virginia University	145	142	3	16	7	20	10	4	—	0	[4]	40	45	3	57	88
54. University of Wisconsin	146	118	28	18	6	20	4	0	—	0	9+	25	45	19	57+	89
55. University of Wyoming.*	124.6	110.6	14	18	6	18	0	0	8	0	—	28	32.6	14	50	74.6

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* Figures reduced to semester-hours from a term or quarter basis.

** Examination required.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

[1] 3 hours summer in addition.

[2] On an average 14 elective credits are taken in major departments.

[3] Included in total.

[4] Includes 5 hours summer work.

TABLE VIII.

ELECTRICAL ENGINEERING, 1924–1925—*Continued.*

Graduation Requirements in 23 Privately Controlled Institutions.

Names of Institutions.	Total Semester Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Electrical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Yale University	136	115	21	12	12	17	12	0	0	0	(21)	28	34	21	53	83
2. George Washington University	140	136	4	12	6	20	6	6	0	0	—	36	50	4	50	90
3. Catholic University of America	183	183	0	22	12	28	0	6	0	15	0	44	56	0	83	100
4. Howard University.*	175	175	0	20	10	16.7	10	0	15	0	0	30	73.3	0	71.7	103.3
5. Armour Institute of Technology	184	181	3	18	10	28.5	12	0	—	4	0	47.5	61	3	72.5	111.5
6 University of Notre Dame	162	158	4	24	10	24	3	0	—	14	0	48	35	4	75	87
7. Rose Polytechnic Institute	143	124	19	17	8	15	2	10	4	0	(13)	32	55	(6)	56	87
8. Johns Hopkins University	159	153	6	18	6	22	6	8[1]	—	0	4[2]	49	44	2[3]	64	95
9. Harvard University	111	105	6	12	6	12	6	0	0	0	6	33	36	—	42	69
10. Massachusetts Institute of Technology	169.7	163.7	6	14	15	26	6	0	12	0	—	52.5	38.2	6	73	96.7
11. Washington University (St. Louis)	148	136	12	17	8	20	6	0	4	0	—	36	45	12	55	93
12. Princeton University	147	141	6	12	8	23	14	12	2	0	—	26	44	6	71	76
13. Polytechnic Institute of Brooklyn	178	174	4	17	13	24.5	14	0	4	0	—	52	48.5	4	72.5	105.5
14. Clarkson College of Technology.*	144	144	0	18	6	24	14	0	4	0	0	48.5	30	0	66	78
15. Union College	148	142	6	28	14	16	7	10	0	2	—	33	32	6	77	71
16. Syracuse University	172	170	2	22	8	18	3	0	0	0	0	52	67	2	51	121
17. Case School of Applied Science	168	168	0	21	12	21	2	12	7	0	0	50	43	0	75	93
18. Lehigh University	162	162	—	16	9	23	6	6	14	4	—	54	30	—	78	84
19. Lafayette College	142	133	9	20	9	19	6	0	4	8	—	26	41	9	66	76
20. Bucknell University	149	139	10	17	6	32	0	12	0	2	—	35	32	10	72	77
21. Swarthmore College	144	142	2	21	10	24	16	12	—	—	—	27	32	2	83	61
22. Carnegie Institute of Technology.†	142.6	139.6	3	18	6	18	12	0	4.6	0	—	49	32	3	58.6	84
23. University of Pittsburgh	153	148	5	14	14	26	5	0	4	7	4	43	35	1	74	79

* Figures reduced to semester hours from a term or quarter basis.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

† Reduced from Carnegie Institute units.

[1] Or Military Training.

[2] Includes 2½ hours summer survey.

[3] Senior elective not designated technical.

ANALYSIS OF GRADUATION REQUIREMENTS IN ELECTRICAL ENGINEERING

Total Graduation Requirements.—In the list of seventy-eight institutions included in this study there are forty-seven different cases of total graduation requirements. These totals vary from 111 to 184 semester-hour credits.

In the following tables are given in semester-hour credits the principal frequencies or modal tendencies of the total graduation requirements in electrical engineering; and likewise the minimum, maximum and median figures.

TOTAL GRADUATION REQUIREMENTS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	No. of Graduation Requirements in Semester-hour Credits.
1	0	1	111
5	5	0	124 to 129
10	9	1	130 to 139.5
31	21	10	140 to 149
13	11	2	150 to 159.3
10	6	4	160 to 169.6
6	3	3	170 to 179
2	0	2	183 and 184

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL GRADUATION REQUIREMENTS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	111	124.6	111
Maximum........	184	176	184
Median..........	145	145	149

Total Prescribed Credits.—The following tables show the principal frequencies or modal tendencies in total prescribed semester-hour credits in electrical engineering curricula; also, the minimum, maximum, and median figures.

TOTAL PRESCRIBED CREDITS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	No. of Prescribed Semester-hour Credits.
3	2	1	105 to 110.6
8	7	1	111.7 to 119
8	7	1	120 to 129.9
20	15	5	130.6 to 139.6
15	10	5	140 to 148
11	9	2	152 to 158.6
7	4	3	170 to 175
2	0	2	181 and 183

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL PRESCRIBED CREDITS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	105	110	105
Maximum........	183	176	183
Median..........	139	136	144

Total Elective Credits.—The following tables show the principal frequencies or modal tendencies in the total elective semester-hour credits in electrical engineering curricula; there are also included the minimum, maximum, and median figures.

TOTAL ELECTIVE CREDITS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	No. of Elective Sem.-hour Credits.
21	16	5	0
10	3	7	2 to 4.7
20	13	7	5 to 9.4
17	14	3	10 to 19
8	7	1	20 to 28
1	1	0	30
1	1	0	53

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ELECTIVE CREDITS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	0 or 2	0 or 3	0 or 2
Maximum........	53	53	21
Median..........	6	7	4

These tables show that 27 per cent of the schools—approximately 30 per cent of the public, and 22 per cent of the private institutions—offer no electives in the electrical engineering curriculum.

Requirements in Mathematics.—The tables following show the principal frequencies or modal tendencies for graduation requirements in mathematics.

REQUIREMENTS IN MATHEMATICS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Mathematics.
6	2	4	12
8	7	1	16
16	12	4	18
16	14	2	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	12	12	12
Maximum........	28	25	28
Median..........	18	19	17

Requirements in English.—The tables following show the principal frequencies or modal tendencies for graduation requirements in English, including also the minimum, maximum, and median figures.

REQUIREMENTS IN ENGLISH, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in English.
1	1	0	0[1]
20	14	6	6
11	7	4	8
10	6	4	10
16	13	3	12

[1] The University of California requires an examination in English.

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN ENGLISH.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum	0 or 2	0 or 2	0 or 6
Maximum	16	16	15
Median	8.7	8.7	9

Requirements in Physical Science.—The next tables show the principal frequencies or modal tendencies for graduation requirements in physical science, including also the minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL SCIENCE, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Phys. Science.
5	4	1	16
10	8	2	18
7	5	2	20
14	13	1	22
7	4	3	24

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL SCIENCE, ELECTRICAL ENGINEERING CURRICULA.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum	12	12	12
Maximum	44	44	32
Median	20	20	Bet. 20 and 21

Requirements in Social Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in social science, including, also, minimum, maximum, and median figures.

REQUIREMENTS IN SOCIAL SCIENCE, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Social Science.
20	18	2	0
8	8	0	4
16	9	7	6
12	10	2	7 to 10
10	3	7	12 to 18

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	0 or 2	0 or 2	0 or 2
Maximum........	18	18	16
Median..........	5	4	6

These tables show that nearly 26 per cent of all the institutions—nearly 33 per cent of the public, and nearly 9 per cent of the private institutions of our list—do not prescribe social science.

Requirements in Foreign Language.—In the following tables are given the principal frequencies or modal tendencies for graduation requirements in foreign language including also the minimum, maximum, and median figures.

REQUIREMENTS IN FOREIGN LANGUAGE, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Foreign Language.
55	42	13	0
1	1	0	4
7	4	3	6
3	1	2	10
6	2	4	12
1	1	0	14
1	1	0	16

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN FOREIGN LANGUAGE.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	0 or 4	0 or 4	0 or 6
Maximum........	16	16	16
Median..........	0	0	0

These tables show that more than 70 per cent of all the institutions—76 per cent of the public and 26 per cent of the private institutions—do not prescribe foreign language for graduation in electrical engineering.

Requirements in Physical and Military Training, and Hygiene.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical and military training, including hygiene.

REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, INCLUDING HYGIENE, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Physical and Military Training.
24	13	11	0
3	2	1	2
12	6	6	4
11	9	2	4.6 to 7
12	12	0	8
5	5	0	9 to 10
11	8	3	12 to 21.3

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	0 or 2	0 or 2	0 or 2
Maximum........	21.3	21.3	15
Median..........	4	6.6	2

The foregoing tables show that over 30 per cent of all of the institutions—nearly 24 per cent of the public, and nearly one-half of the private institutions—do not prescribe physical and military training for graduation in electrical engineering.

Requirements in Prescribed Miscellaneous Subjects.—As in mechanical engineering, fourteen of our list prescribe certain subjects for graduation in electrical engineering in addition to those already mentioned. These subjects as mentioned heretofore include Bible, religion, psychology, philosophy and orientation courses.

Non-Engineering Electives.—Fifteen institutions of the seventy-eight specify non-engineering electives as a part of graduation requirements in electrical engineering. The more important frequencies are given in the following table:

NON-ENGINEERING ELECTIVES, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Non-engineering Electives.
63	45	18	0
3	2	1	6
4	4	0	12
8	4	4	Other credits

This table shows the relative insignificance of the non-engineering electives in the curricula in electrical engineering. (This does not include specific options.)

Total Non-Engineering Subjects.—The following table indicates the principal frequencies or modal tendencies in total non-engineering subjects, including the minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in Non-Engineering Subjects.
6	5	1	40 to 49
23	17	6	50 to 59
22	19	3	60 to 69
16	5	11	70 to 79
11	9	2	80 to 90

MINIMUM, MAXIMUM, AND MEDIAN FIGURES: TOTAL NON-ENGINEERING SUBJECTS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	40.7	40.7	42
Maximum........	88.3	88.3	83
Median..........	64	62	71

Total Engineering Subjects.—The subsequent tables show the principal frequencies or modal tendencies in total engineering subjects including minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hr. Credits Prescribed in Engineering Subjects.
8	6	2	60 to 69
16	10	6	70 to 79
30	25	5	80 to 89
14	9	5	90 to 99
8	4	4	100 to 111.5
1	0	1	121

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	58	58	61
Maximum........	121	106	121
Median..........	84	84	84

Specific Subjects in Electrical Engineering.—The following tables give the principal frequencies or modal tendencies in specific subjects in electrical engineering. In general the specific subjects include electrical instruments, electrical wiring, assembly and installation, principles of electrical engineering, alternating currents, direct currents, electrical engineering testing, alternating current machinery, advanced electrical machinery, alternating current design, direct current design, electric lighting, electric power transmission, transformer and induction motor design, telephone and telegraph engineering, radio engineering, dynamo laboratory, etc., industrial applications of electricity, and other similar specific subjects such as advanced courses in physics relating to electrical theory and measurements given in junior or senior years of college. The minimum, maximum, and median figures are also given.

SPECIFIC SUBJECTS IN ELECTRICAL ENGINEERING, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hr. Credits Prescribed in Specific Electrical Engineering Subjects.
2	2	0	15 and 19
19	15	4	20 to 29
30	23	7	30 to 39
18	11	7	50 to 55

MINIMUM, MAXIMUM, AND MEDIAN; SPECIFIC SUBJECTS IN ELECTRICAL ENGINEERING.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum........	15	15	26
Maximum........	55	55	54
Median..........	34	33	36

Requirements in Engineering Subjects other than Electrical Engineering.—The tables following show the principal frequencies or modal tendencies in other engineering subjects; also, the minimum, maximum, and median figures.

OTHER ENGINEERING SUBJECTS, ELECTRICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hour Credits Prescribed in "Other Engineering Subjects."
1	1	0	17
1	1	0	26
33	22	11	30 to 39.5
25	19	6	40 to 49
13	10	3	50 to 59
4	2	2	60 to 69
1	0	1	73.3

MINIMUM, MAXIMUM, AND MEDIAN; OTHER ENGINEERING SUBJECTS.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum.	26	26	30
Maximum.	73.3	63	73.3
Median.	42	42	Bet. 38 and 41

Requirements in Engineering Electives.—The following tables show the principal frequencies or modal tendencies in the engineering electives of electrical engineering curricula, including also the minimum, maximum, and median figures.

ENGINEERING ELECTIVES, ELECTRICAL ENGINEERING CURRICULA.

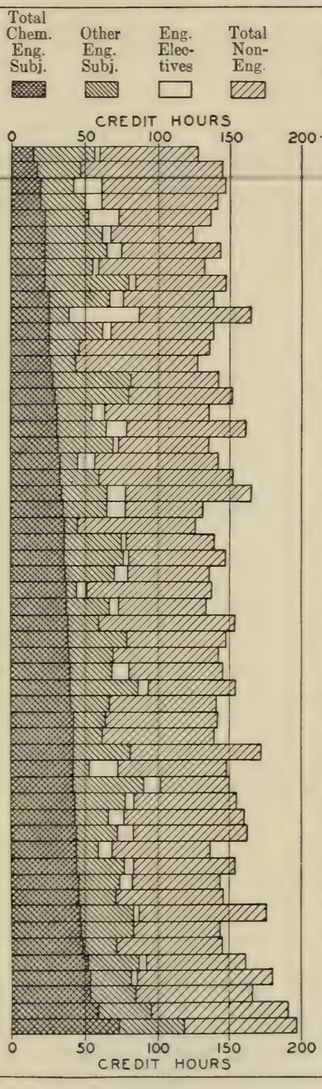
Number of Cases.	In Public Institutions.	In Private Institutions.	Sem.-hr. Credits Prescribed in Engineering Electives.
25	19	6	0
31	17	14	1 to 10
15	13	2	10 to 20
5	4	1	20 to 30
2	2	0	53 and 81

MINIMUM, MAXIMUM, AND MEDIAN; ENGINEERING ELECTIVES.

Requirements.	For All Institutions (78).	For Public Institutions (55).	For Private Institutions (23).
Minimum.	0 or 3	0 or 3	0 or 1
Maximum.	81	81	21
Median.	Bet. 4.7 and 5.3	6	3

The foregoing tables show that approximately 32 per cent of all the engineering schools do not allow engineering electives (general options are not included in this statement).

E. GRADUATION REQUIREMENTS IN CHEMICAL ENGINEERING



	Names of Institutions	Total Grad. Req.	Total Chemical Eng. Subj.	Other Eng. Subj.	Eng. Elect.	Total Non Eng. Subj.
1	University of Missouri	128	15	43	4	66
2	North Carolina State College	146	18	30.7	0	97.3
3	University of Alabama	147.5	20	23.5	20	84
4	University of Michigan	140	20	30	11	79
5	University of California	136	24	29	21	62
6	University of Nebraska	125	24	40	6	55
7	University of New Mexico	144	24	43	10	67
8	University of Tennessee	133	24	33	3	73
9	West Virginia University	148	24	58	5	61
10	University of Arkansas	139	26	42	9	62
11	Colorado School of Mines	165	26	13	48	78
12	Princeton University	138	26	37	6	69
13	Swarthmore College	137	26	22	(4)*	89
14	University of South Dakota	128	27	18	(9)*	83
15	University of Colorado	142	29.3	53.3	0	59.3
16	University of Idaho	152	30	51	0	71
17	Yale University	136	32	25	9	70
18	Notre Dame University	163	32	35	14	82
19	University of Florida	136	33	39	3	61
20	University of New Hampshire	143.3	34.7	12.6	12	84
21	Virginia Polytechnic Institute	152	34.7	27.1	—	90.2
22	Purdue University	167	35	32.3	13	86.7
23	University of Washington	132	35.3	31.3	12.7	52.7
24	State College of Washington	128	36	9	0	83
25	George Washington University	140	36	40	2	62
26	Carnegie Institute of Technology	148.6	36	42	3	67.6
27	Michigan State College	136	36.7	34	8.7	56.6
28	Oregon Agricultural College	138	37	7.3	7.7	86
29	Tufts College	135	37	31	6	61
30	University of Delaware	153	38	22	0	93
31	Syracuse University	149	38	42	0	69
32	Georgia School of Technology	142.4	39	31	0	72.4
33	University of Minnesota	145.3	39.3	28.7	12.6	64.7
34	Ohio State University	155.3	39.3	47.3	7.4	61.3
35	University of Kansas	141	40	27	0	74
36	Louisiana State University	141.3	42	22.6	—	76.7
37	University of Maine	140	42	21	(13)*	77
38	Lehigh University	173	42	40	0	91
39	Bucknell University	149	42	12	20	75
40	University of Wisconsin	150	42	49	12	47
41	Lafayette College	156	43	36	6	71
42	Alabama Polytechnic Institute	161.4	43.5	22.3	12	83.6
43	A. & M. College of Texas	164.5	44	29.5	12	79
44	University of Illinois	137	45	16	10	66
45	University of Pittsburgh	155	45	33	7	70
46	Iowa State College	144	46	28.7	9.3	60
47	Montana State College	145.3	46	26	(24.6)*	73.3
48	Massachusetts Institute of Tech.	178.2	47.5	35.7	4	91
49	Rose Polytechnic Institute	143	48	37	(23)*	58
50	Clarkson College of Technology	143.3	49.3	24	0	70
51	Tulane University of Louisiana	162	52	35	6	69
52	Polytechnic Institute of Brooklyn	181	54	29.5	4	93.5
53	Case School of Applied Science	167	54	32	0	81
54	Catholic University of America	190.5	60	37.5	0	93
55	Armour Institute of Technology	195.5	73.5	45.5	—	76.5

* Options—not included in Total Graduation Requirements.

GRAPH O. Total Semester-Hour Requirements in Principal Subject Groups, Chemical Engineering Curricula.

TABLE IX.

Chemical Engineering, 1924–1925.

Graduation Requirements in 35 Publicly Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Chemical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Alabama Polytechnic Institute	161.4	149.4	12	20	16	30	5	6	6.6	0	—	43.5	22.3	12	83.6	77.8
2. University of Alabama	147.5	127.5	20	20	4	50	6	0	4	0	—	20	23.5	20	84	63.5
3. University of Arkansas	139	119	20	19	6	22	0	0	4	0	11[1]	26	42	9	62	77
4. University of California.[2]	136	115	21	12	**	34	2	—	8	0	—	24	29	21	56	74
5. University of Colorado.*	142	142	0	18	8.6	30.7	0	0	2	0	0	29.3	53.3	0	59.3	82.7
6. Colorado School of Mines	165	117	48	20	6	44	0	0	8	0	—	26	13	48[3]	78	87
7. University of Delaware	153	153	0	24	12	32	1	12	12	0	0	38	22	0	93	60
8. University of Florida	136	133	3	16	8	26	3	0	8	0	—	33	39	3	61	75
9. Georgia School of Technology	142.4	142.4	0	23.7	15	12	3	12	6.7	0	0	39	31	0	77.4	70
10. University of Idaho	152	152	0	18	10	26	0	9	8	0	0	30	51	0	71	81
11. University of Illinois	137	127	10	15	6	30	0	8	7	0	—	45	16	10	66	71
12. Purdue University	167	154	13	20	9	36 +	3	12	6.7	0	—	35	32.3	13	86.7	80.3
13. Iowa State College.*	144	134.7	9.3	19.3	8.7	28	0	0	4	0	—	46	28.7	9.3	60	84
14. University of Kansas	141	141	—	20	8	30	6	10	—	0	0	40	27	0	74	67
15. Louisiana State University.*	141.3	141.3	—	16.7	12	32	0	12	4	0	—	42	22.6	—	76.7	64.6
16. University of Maine	140	122	18	16	12	31	—	—	—	—	18	42	21	(13)	77	63
17. University of Michigan	140	113	27	16	6	38[4]	3	—	0	—	16[5]	20	30	11	79	61
18. Michigan State College.*	136	121.3	14.7	16	8	17.3	1.3	—	8	0	6	36.7	34	8.7	56.6	79.4
19. University of Minnesota.*	145.3	132.7	12.6	16.7	6	28	0	14	—	0	—	39.3	28.7	12.6	61.7	80.6
20 University of Missouri	128	124	4	20	12	21	5	0	8	0	—	15	43	4	66	62
21. Montana State College.*	145.3	145.3	—	18	10	33.3	4	0	8	0	—	46	26	(24.6)	73.3	72
22. University of Nebraska	125	119	6	16	4	26	3	0	4	2	0	24	40	6	55	70
23. University of New Hampshire	143.3	131.3	12	22	6	36	0	12	8	0	0	34.7	12.6	12	84	59.3
24. Universtiy of New Mexico	144	122	22	18	9	26	—	—	—	2	12	24	43	10	67	77
25. North Carolina State College.*	146	128	18	20	12	37.3	2	0	8	0	18	18	30.7	0	97.3	48.7
26. Ohio State University.*	155.3	147.9	7.4	20	6	28.6	0	0	6.7	0	0	39.3	47.3	7.4	61.3	94
27. Oregon Agricultural College	138	130.3	7.7	16	6	30	6	18	10	0	0	37	7.3	7.7	86	52
28. University of South Dakota	128	128	(9)[6]	18	3	22	6	—	12	22	—	27	18	(9)[6]	83	45
29. University of Tennessee	133	124	9	20	12	25	0	0	10	0	6	24	33	3[7]	73	60
30. A. & M. College of Texas	164.5	152.5	12	22	16	24	9	0	8	0	—	44	29.5	12	79	85.5
31. Virginia Polytechnic Institute.*	152	136	16	20	12	28.7	8	0	5.1	.4	16	34.7	27.1	—	90.2	61.8
32. University of Washington.*	132	119.3	12.7	12	2	32	0	0	6.7	0	—	35.3	31.3	12.7	52.7	79.3
33. State College of Washington	128	128	0	16	8	44	8	0	7	0	0	36	9	0	83	45
34. West Virginia University	148	143	5	16	7	31	3	0	4	0	0	24	58	5	61	87
35. University of Wisconsin	150	137	13	18	6	23	0	0	—	—	—	48	53	12	47	103

* Figures have been reduced from term to semester-hours.

** Examination required.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives.

[1] Subject to consent of authorities.

[2] Suggested curr. in chem. tech.

[3] Includes some non-engineering elect.

[4] Includes all chemistry courses.

[5] Language and other group.

[6] Option.

[7] Not definitely technical.

TABLE IX.

CHEMICAL ENGINEERING, 1924–1925.—*Continued.*

Graduation Requirements in 20 Privately Controlled Institutions.

Names of Institutions.	Total Semester-Hours.	Total Prescribed Hours.	Total Elective Hours.	Mathematics.	English.	Physical Science.	Social Science.	Foreign Language.	Physical and Military Training.	Miscellaneous Subjects.	Non-Engineering Electives.	Chemical Engineering.	Other Engineering.	Engineering Electives.	Total Non-Engineering.	Total Engineering.
1. Yale University	136	115	21	12	12	22	12	(12)[1]	0	0	12[2]	32	25	9 +[2]	70	66
2. George Washington University	140	138	2	12	6	32	6	6	0	0	—	36	40	2	62	78
3. Catholic University of America	190.5	190.5	0	18	6	42	6	6	0	15	0	60	37.5	0	93	97.5
4. Armour Institute of Technology	195.5	195.5	(6)	18	9	35.5	10	0	—	4	0	73.5	45.5	(6)	76.5	119
5. University of Notre Dame	163	149	14	18	10	40	0	0	0	14	—	32	35	14	82	81
6. Rose Polytechnic Institute	143	143	(23)	17	8	17	2	10	4	0	—	48	37	(23)	58	85
7. Tulane University of Louisiana	162	156	6	18	12	31	6	0	2	0	—	52	35	6	69	93
8 Massachusetts Institute of Technology	178.2	174.2	4	11	12	44	6	6	12	0	—	47.5	35.7	4	91	87.2
9. Tufts College	135	129	6	13	6	22	6	12	2	0	—	37	31	6	61	74
10. Princeton University	138	132	6	9	8	24	14	12	2	0	—	26	37	6	69	69
11. Polytechnic Institute of Brooklyn	181	171	10	20	13	42.5	8	0	4	0	6	54	29.5	4	93.5	87.5
12. Clarkson College of Technology.*	143.3	143.3	0	16	6	28	16	0	4	0	0	49.3	24	0	70	73.3
13. Syracuse University	149	149	0	18	6	30	3	12	0	0	0	38	42	0	69	80
14. Case School of Applied Science	167	167	0	18	12	33	2	9	7	0	0	54	32	0	81	86
15. Lehigh University	173	170	3	15	3 +	45	9	6+	6	4	3	42	40	0	91	82
16. Lafayette College	156	150	6	17	6	36	0	0	4	8	—	43	36	6	71	85
17. Bucknell University	149	129	20	17	10	40	0	6	0	2	(20)[3]	42	12	20[3]	75	74
18. Swarthmore College	137	133	4	21	9	21	12	18	—	4	4	26	22	(4)[4]	89	48
19. Carnegie Institute of Technology.†	148.6	145.3	3	18	6	21	18	0	4.6	—	—	36	42	3	67.6	81
20. University of Pittsburgh	155	148	7	14	14	30	4	0	4	4	0	45	33	7	70	85

* Figures have been reduced from term to semester-hours.

( ) indicates that the electives are not always clearly defined either as engineering or non-engineering electives

† Reduced from Carnegie Institute system to semester-hour credits.

[1] Highly recommended.

[2] Estimated.

[3] Electives are chosen from a list of both technical and non-technical subjects.

[4] Largely non-technical.

ANALYSIS OF GRADUATION REQUIREMENTS IN CHEMICAL ENGINEERING

Total Graduation Requirements.—There are thirty-seven different cases of total graduation requirements in chemical engineering in the list of fifty-five colleges of engineering included in this section of our study. These totals vary from 125 to 195.5 semester-hour credits.

The following tables show in terms of semester-hour credits the principal frequencies or modal tendencies of total graduation requirements in chemical engineering in thirty-five public and twenty private institutions; the minimum, maximum, and median figures are also given.

TOTAL GRADUATION REQUIREMENTS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Graduation Requirements in Semester-hour Credits.
4	4	0	125 to 128
12	8	4	130 to 139
20	14	6	140 to 149
7	5	2	150 to 156
7	4	3	160 to 167
5	0	5	173 to 195.5

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL GRADUATION REQUIREMENTS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	125	125	135
Maximum........	195.5	167	195.5
Median..........	144	142	Bet. 149 and 155

Total Prescribed Credits.—The following tables show the principal frequencies or modal tendencies in the total prescribed semester-hour credits in chemical engineering including also the minimum, maximum, and median figures.

TOTAL PRESCRIBED CREDITS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Prescribed Semester-hour Credits.
7	6	1	113 to 119.3
12	10	2	120 to 129
10	7	3	130 to 138
14	8	6	140 to 149
5	4	1	150 to 156
6	0	6	167 to 195.5

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL PRESCRIBED CREDITS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	113	113	115
Maximum........	195.5	154	195.5
Median..........	137	131.3	Bet. 148 and 149

Total Elective Credits.—The following tables show the principal frequencies or modal tendencies in the total elective semester-hour credits in chemical engineering and include also the minimum, maximum, and median figures.

TOTAL ELECTIVE CREDITS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Number of Elective Semester-hour Credits.
15	9	6	0
7	2	5	1 to 4
11	6	5	5 to 9.3
14	12	2	10 to 18
7	5	2	20 to 27
1	1	0	48

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL ELECTIVE SEMESTER-HOUR CREDITS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	0 or 2	0 or 3	0 or 2
Maximum........	27	48	21
Median..........	6	12	4

These tables show that 27 per cent of all the schools—26 per cent of the public and 30 per cent of the private institutions—offer no electives in the chemical engineering curriculum.

Requirements in Mathematics.—The following tables show the principal frequencies or modal tendencies for graduation requirements in mathematics, also the minimum, maximum, and median figures.

REQUIREMENTS IN MATHEMATICS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in Mathematics.
9	8	1	16
13	6	7	18
11	10	1	20

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN MATHEMATICS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	9	12	9
Maximum........	24	24	21
Median..........	18	18	17

Requirements in English.—The following tables show the principal frequencies or modal tendencies for graduation requirements in English including the minimum, maximum, and median figures.

REQUIREMENTS IN ENGLISH, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits Prescribed in Mathematics.
1	1	0	0[1]
16	9	7	6
6	4	2	8
11	7	4	12

[1] The University of California requires an examination in English.

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN ENGLISH.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum	0 or 2	0 or 2	0 or 3
Maximum	16	16	14
Median	8	8	8

Requirements in Physical Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical science, including also minimum, maximum, and median figures.

REQUIREMENTS IN PHYSICAL SCIENCE, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hours Prescribed in Physical Science.
3	2	1	12 to 17
20	14	6	20 to 28.7
23	16	7	30 to 38
8	2	6	40 to 45
1	1	0	50

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL SCIENCE.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum	12	12	17
Maximum	50	50	45
Median	30	30	Bet. 31 and 32

Requirements in Social Science.—The following tables show the principal frequencies or modal tendencies for graduation requirements in social science including the minimum, maximum, and median figures.

REQUIREMENTS IN SOCIAL SCIENCE, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hours Prescribed in Social Science.
18	15	3	0
7	6	1	3
9	4	5	6

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN SOCIAL SCIENCE.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	0 or 1	0 or 1	0 or 2
Maximum........	9	9	18
Median..........	3	2	6

The foregoing tables show that nearly 33 per cent of all the institutions—40 per cent of the public and more than 10 per cent of the private institutions—do not prescribe social science.

Requirements in Foreign Language.—The following tables show the principal frequencies or modal tendencies for graduation requirements in foreign language, also the minimum, maximum, and median figures.

REQUIREMENTS IN FOREIGN LANGUAGE, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-hour Credits Prescribed in Foreign Language.
32	24	8	0
7	1	1	6
8	4	4	12

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN FOREIGN LANGUAGE.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	0 or 6	0 or 6	0 or 6
Maximum........	18	18	18
Median..........	0	0	6

These tables show that nearly 60 per cent of the institutions—70 per cent of the public and 40 per cent of the private institutions—do not prescribe foreign language for graduation in chemical engineering.

Requirements in Physical and Military Training, and Hygiene.—The following tables show the principal frequencies or modal tendencies for graduation requirements in physical and military training, including hygiene.

REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING, INCLUDING HYGIENE, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	Number of Public Institutions.	Number of Private Institutions.	Semester-hours Prescribed in Physical and Military Training, Etc.
14	6	8	0
11	6	5	4
5	5	0	6.7
10	10	0	8

MINIMUM, MAXIMUM, AND MEDIAN; REQUIREMENTS IN PHYSICAL AND MILITARY TRAINING.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	0 or 2	0 or 2	0 or 2
Maximum........	12	12	12
Median..........	4	6.7	2

The foregoing tables show that only approximately 25 per cent of all of the engineering schools—17 per cent of the public and 40 per cent of the private—do not prescribe physical and military training, etc.

Requirements in Prescribed Miscellaneous Subjects.—Twelve of the fifty-five institutions under consideration prescribe certain subjects for graduation in chemical engineering in addition to those indicated above. These subjects include for the most part, Bible, religion, psychology, philosophy, and orientation courses. The lowest requirement is 0.4 semester-hour credit; the highest is 22.

Non-Engineering Electives.—Thirteen institutions of the fifty-five definitely indicate non-engineering electives as a part of the graduation requirements in chemical engineering.

Total Non-Engineering Subjects.—The following tables show the principal frequencies or modal tendencies in total-non-engineering subjects; also the minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Non-engineering Subjects.
1	1	0	47
5	4	1	50 to 60
16	10	6	60 to 70
16	10	6	70 to 80
10	7	3	80 to 90
7	3	4	90 to 97.3

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN NON-ENGINEERING SUBJECTS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	47	47	58
Maximum........	97.3	97.3	93.5
Median..........	72.4	73	Bet. 70 and 71

Total Engineering Subjects.—The following tables show the principal frequencies or model tendencies in total engineering subjects, also minimum, maximum, and median figures.

TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Engineering Subjects.
3	2	1	45 to 48
2	2	0	52 to 59.3
11	9	2	60 to 69
15	11	4	70 to 79
18	8	10	80 to 87.5
5	2	3	93 to 119

MINIMUM, MAXIMUM, AND MEDIAN; TOTAL REQUIREMENTS IN ENGINEERING SUBJECTS.

Requirements.	In All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	45	45	48
Maximum........	119	103	119
Median..........	77	72	Bet. 81 and 82

Requirements in Specific Subjects in Chemical Engineering.—The following tables show the principal frequencies or modal tendencies in the specific subjects of chemical engineering. For the purpose of this study all freshman and sophomore courses in chemistry have been counted as a part of the requirements in physical science in the non-engineering group. All other chemistry courses including those in applied chemistry are designated chemical engineering.

SPECIFIC SUBJECTS IN CHEMICAL ENGINEERING, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Specific Chemistry Engineering Subjects.
2	2	0	15 to 18
13	11	2	20 to 29
19	13	6	30 to 39
16	9	7	40 to 49
3	0	3	52 to 54
1	0	1	60
1	0	1	73.5

MINIMUM, MAXIMUM, AND MEDIAN; SPECIFIC SUBJECTS IN CHEMICAL ENGINEERING.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	15	15	26
Maximum........	73.5	48	73.5
Median..........	37	35	Bet. 42 and 43

Requirements in Engineering Subjects other than Chemical Engineering.—The following tables show the principal frequencies or modal tendencies in other engineering subjects, including the minimum, maximum, and median figures.

These subjects include all general subjects in engineering, in addition to specific subjects in mechanical, electrical, and civil engineering that may be prescribed in connection with the technical courses in chemistry or chemical engineering.

OTHER ENGINEERING SUBJECTS, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Other Engineering Subjects.
2	2	0	7.3 to 9
5	4	1	12 to 18
16	12	4	20 to 29
19	8	11	30 to 39
10	5	5	40 to 49
4	4	0	50 to 58

MINIMUM, MAXIMUM, AND MEDIAN FIGURES; OTHER ENGINEERING SUBJECTS.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum........	7.3	7.3	12
Maximum........	58	58	45.5
Median..........	32	29	35

Requirements in Engineering Electives.—The following tables show the principal frequencies or modal tendencies in the engineering electives of chemical engineering curricula, including also the minimum, maximum, and median figures.

ENGINEERING ELECTIVES, CHEMICAL ENGINEERING CURRICULA.

Number of Cases.	In Public Institutions.	In Private Institutions.	Semester-hour Credits in Engineering Electives.
19	12	7	0
21	10	11	2 to 9.3
11	10	1	10 to 14
3	2	1	20 to 21

MINIMUM, MAXIMUM, AND MEDIAN; ENGINEERING ELECTIVES.

Requirements.	For All Institutions (55).	For Public Institutions (35).	For Private Institutions (20).
Minimum	0 or 2	0 or 3	0 or 2
Maximum	48	48	20
Median	5	7.4	4

These tables show that more than 34 per cent of all the engineering schools—34 per cent of the public and 35 per cent of the private institutions—do not allow engineering electives (this does not refer to group options).

BULLETIN NUMBER 11
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF
EVOLUTIONARY TRENDS IN
ENGINEERING CURRICULA

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A STUDY OF EVOLUTIONARY TRENDS IN ENGINEERING CURRICULA

PART I. SCOPE AND METHODS

Purposes and Auspices.—The fact-finding studies included in the present investigation are concerned almost wholly with the present state of engineering education. As a constantly developing process, engineering education cannot be pictured adequately or appraised rightly if presented in static terms alone, but rather needs to be viewed in an evolutionary perspective. The present study traces the trend of evolution in five major engineering curricula in order that their present state may be defined in terms of direction as well as position. These studies have been carried out by the Staff of the investigation, with valuable assistance from the United States Bureau of Education in supplying documentary sources.

Scope.—To represent the general trends throughout the entire group of colleges, ten were chosen which afford a reasonable diversity of origins, status and location, namely: Alabama Polytechnic Institute, Case, Cornell, Illinois, Iowa State College, Lehigh, Massachusetts Institute of Technology, Michigan, Purdue and Wisconsin. Two of these are independent polytechnic institutes; one is an independent university with associated land grant and state-aided colleges; one is an independent university in which engineering holds a dominant position; two are state universities including land grant colleges; three are typical detached land grant institutions; and one a state university without land grant colleges. One is in New England, two in the middle Atlantic states, one in the South, three in the Great Lakes area, and three in the Mississippi valley. The choice of these institutions was also influenced by such practical considerations as the availability of catalogs issued in or near the years of reference, the presentation of curricula in a form that lends itself to quantitative analysis, and the undergraduate nature of the curricula. The group chosen, taken as a whole, is fairly representative of the dominant influences in engineering education during the period of the study.

Curricula in civil, mining, mechanical, electrical and chemical engineering are included in the analyses. With slight deviations in the actual year in a few cases, these curricula have been analyzed as of 1870–71, 1885–86, 1900–01, 1915–16 and 1923–24. Curricula in electrical engineering appear first in the analyses for 1885 and curricula in chemical engineering first in 1900. The cases actually covered by the several analyses are shown in Table 1 on page 555.

Classification of Subjects.—It may be noted that a total of 161 complete curricula have been analyzed. To bring this study within reasonable bounds of time and cost, it was necessary to reduce the method to a series of simple clerical operations. The first step was to classify the subject matter into a limited number of significant groups. It was found that thirteen groups could be made to include all the items of the several curricula with only infrequent and slight accommodations. These groups are as follows: (1) The principal branch of engineering which gives its name to the curriculum; (2) other specific engineering subjects; (3) mechanics and hydraulics; (4) graphics, *i.e.,* drawing, descriptive geometry, etc.; (5) shop work; (6) free electives; (7) physical and natural sciences; (8) mathematics; (9) economics; (10) other social studies, principally history and political science; (11) English; (12) foreign languages; and (13) physical and military training, including hygiene. Restricted electives were divided equally between the subjects from which a choice was permitted. Most of the discretionary cases involved a choice between graphics, mechanics and hydraulics, and the two groups of specific engineering subjects. In each such instance the classification was based on the catalog description of the item in question. In some cases it was necessary to make certain arbitrary classifications; for example, chemistry taught in the first two years of the chemical engineering curriculum was classed under physical science and that given in the last two years under the principal branch of engineering. This particular classification does some violence to nomenclature, but it is convenient for separating the items which contribute to specialization from those which may be considered a part of general education. Astronomy, geology and mineralogy were classified under physical science in all cases, with the result that the degree of specialization in the mining curriculum is somewhat under-stressed. In the main the classifications of individual curricula contain few doubtful items and the composite results are involved in relatively little uncertainty from this source.

Choice of a Unit.—In order to combine the curricula of the ten institutions into a series of composite pictures from which general trends rather than local variations might be inferred, it was necessary to express the content of each subject group in some uniform quantitative unit. Both the past and the present methods of expressing time requirements and evaluating academic credits are so diverse that it seemed necessary to adopt a relative, rather than an absolute, unit. These difficulties were reduced to a minimum by employing as the unit the ''normal academic year,'' representing the total requirements set by an institution for a period of from eight to nine months of approximately continuous work. Wherever summer courses in residence are required, these were counted as an additional requirement and raised the total for the entire curriculum proportionately above the nominal value of four ''years.'' The use of the ''academic year'' as a unit of measure leaves out of account all variations, other than required summer terms, between the quantitative requirements of different institutions, of different years of the course, and of different years of reference.

Quantitative Treatment.—After the subjects had been classified the items were rated according to the specified time allotment or assigned credit value. Where credit values were not expressly stated, the usual rating gave equal values to one hour of class instruction requiring preparation, two hours of practical exercises on which written reports are required, and three hours of practical exercises complete in themselves. Each item was expressed as a percentage of the total requirements of the year in which it occurred. Totals for each of the thirteen subject groups in the complete curriculum were then computed and expressed in units and fractions of a complete academic year. The requirements of the several institutions for a like year in a given curriculum were then averaged to obtain a composite picture. Finally, a synthesis of all the curricula of each given period was made by weighting the averages in accordance with the number of cases under each curriculum title, so that the most general trends might be made evident. The composite results referred to above are given in Tables 2 and 4, on pages 556 and 557.

PART II. DISCUSSION AND GRAPHICAL PRESENTATION OF THE RESULTS

Evolutionary Trends in Curricula.—The first series of charts, Figs. 1 to 5 inclusive, shows the trend of evolution in particular curricula, as analyzed into thirteen subject groups, and Fig. 6 shows the generalized trend, based on the composite of the five curricula examined. The arrangement of the subject groups in each of these diagrams is in the order of increasing specialization, from the bottom upward. A horizontal reference line marked by a zero at the margin is placed at the middle of each diagram. The subject groups which are common to both engineering and general academic education are ranged below this line, while the distinctive technical subjects of engineering, together with the free electives, are ranged above. But for the element of confusion which would result, it would be appropriate to divide the block representing free electives equally above and below the reference line. The arrangement of the chart makes a trend toward increasing specialization directly apparent as an upward displacement of successive bands, and a tendency toward greater concentration on the major branch of engineering is shown by a lengthening of the topmost block. The arrangement of the free electives tends to exaggerate somewhat the indication of specialization. The blocks are shown alternately black and shaded merely to distinguish them more boldly.

It is apparent that the general trend since 1870 has been toward greater specialization and concentration, but there

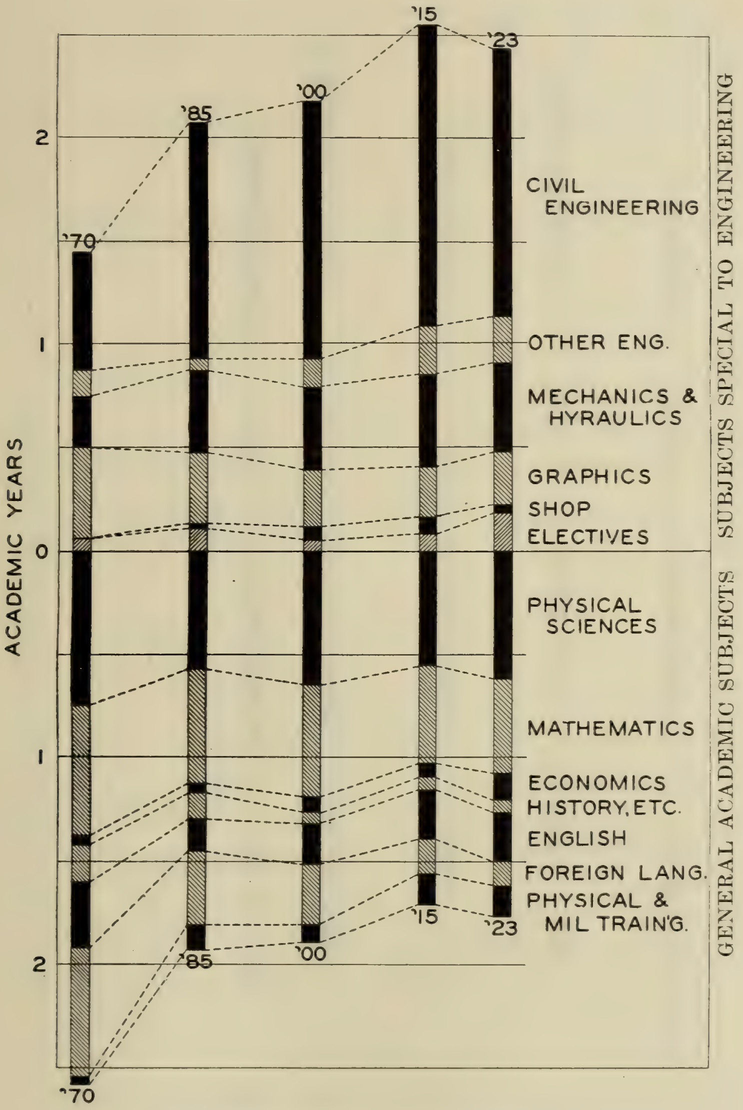

FIG. 1. Evolutionary trends in civil engineering curricula.

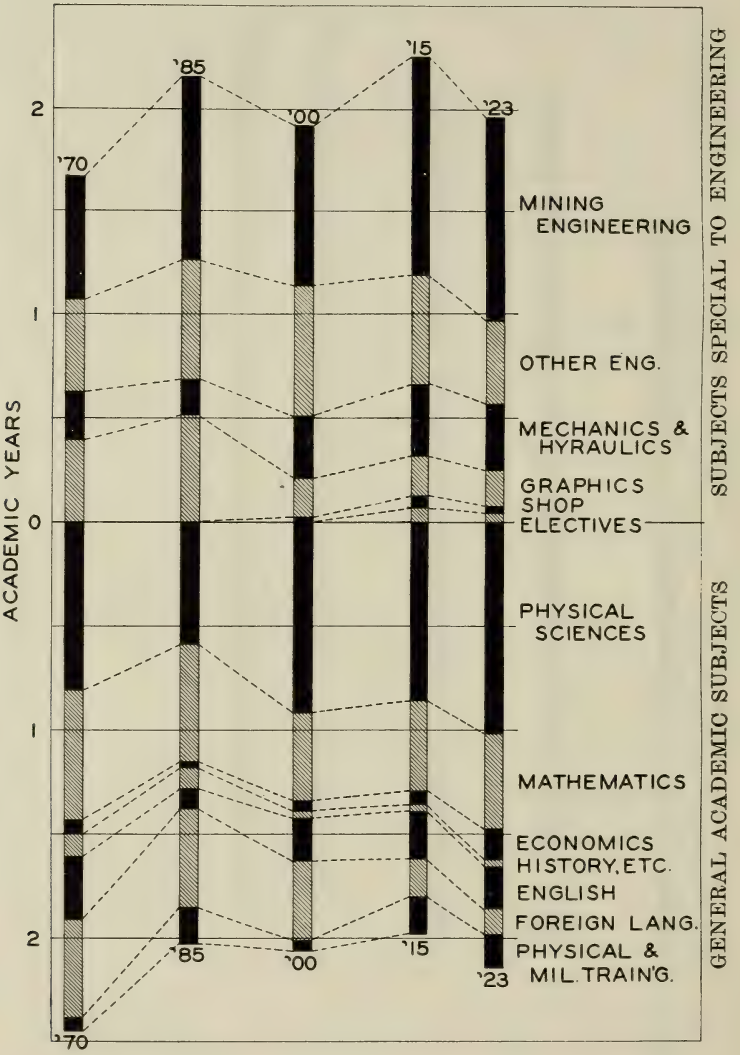

FIG. 2. Evolutionary trends in mining engineering curricula. (Note: Geology and mineralogy are included in physical sciences.)

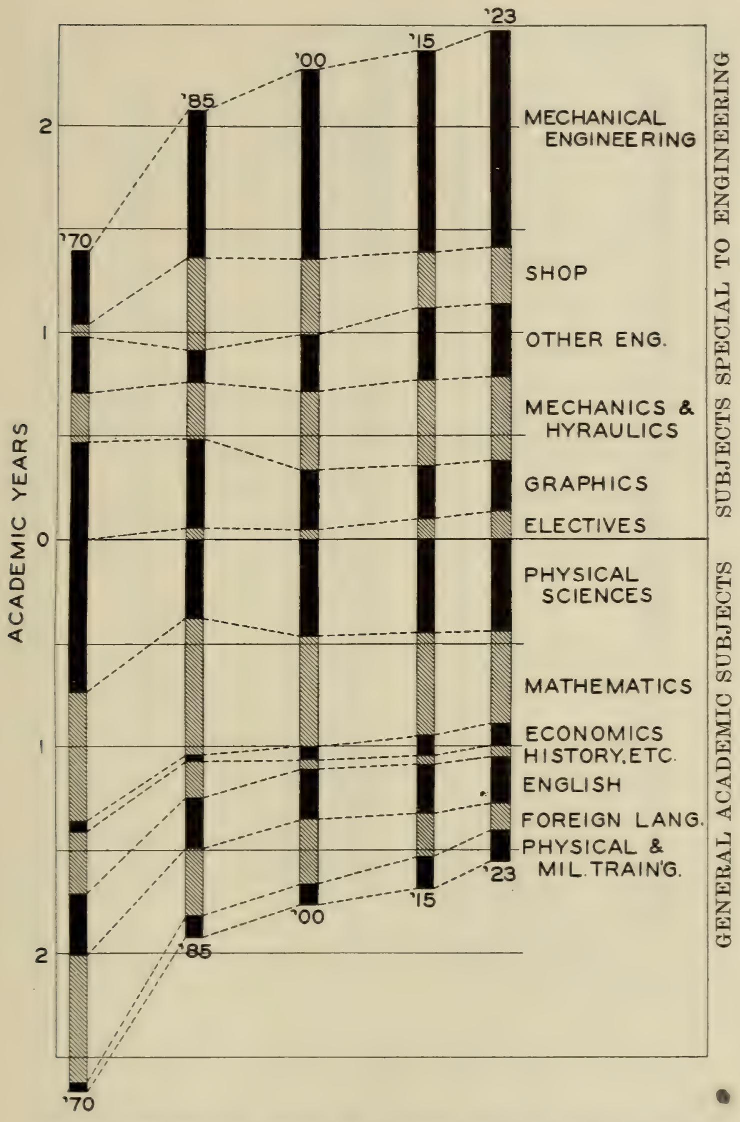

FIG. 3. Evolutionary trends in mechanical engineering curricula.

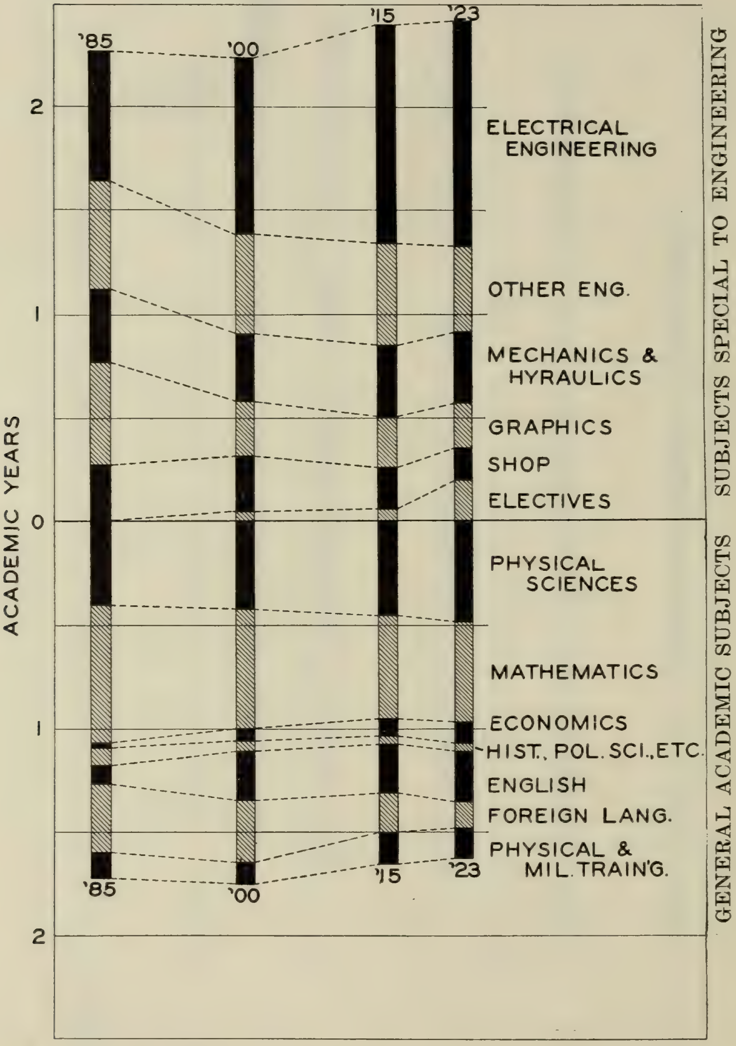

Fig. 4. Evolutionary trends in electrical engineering curricula.

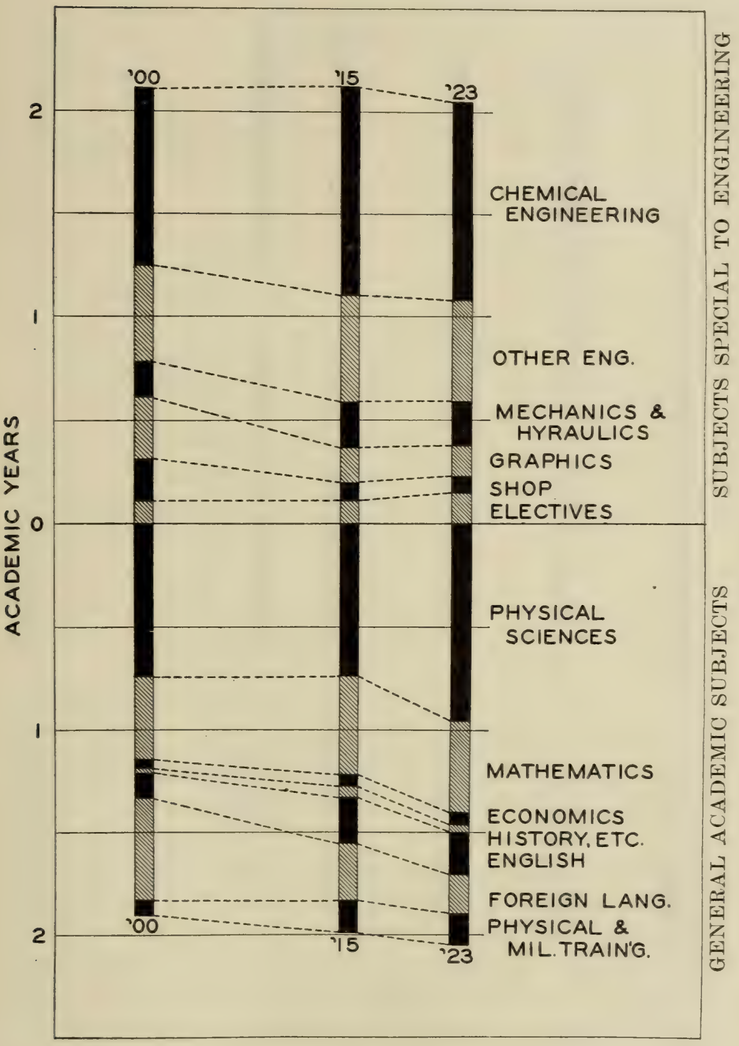

FIG. 5. Evolutionary trends in chemical engineering curricula. (Note: Advanced chemistry is included in chemical engineering.)

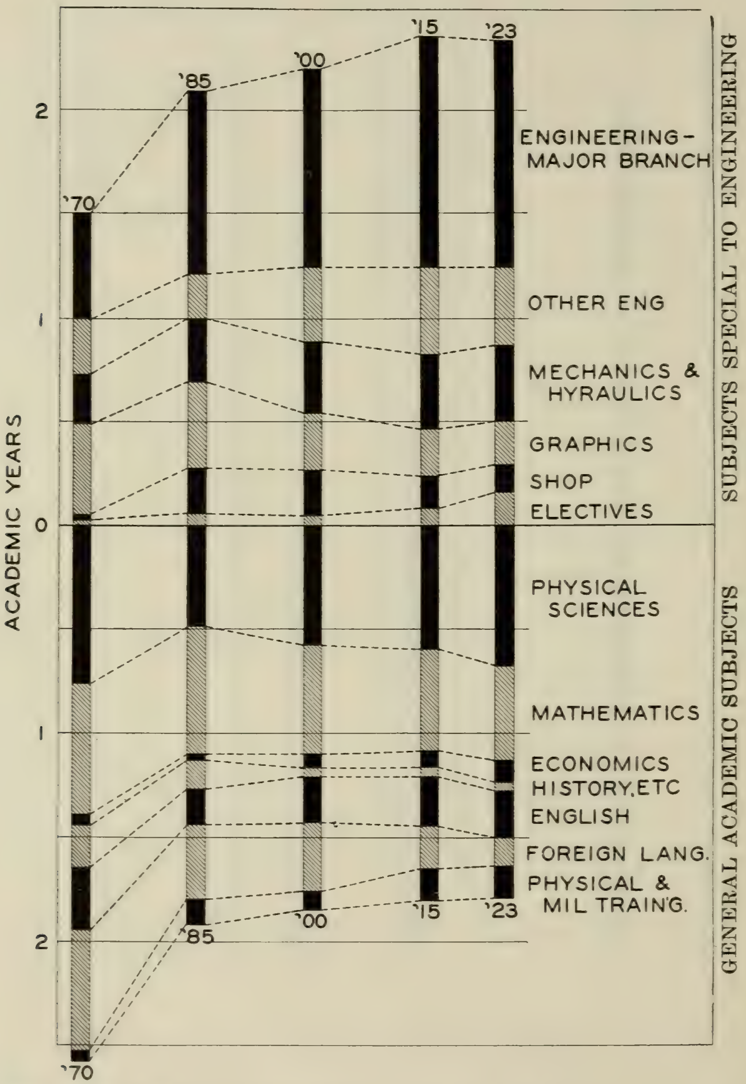

FIG. 6. Evolutionary trends in the composite of all the curricula studied.

are indications that this movement has passed its peak and that a reaction to more general training is developing. Attempts to popularize undifferentiated curricula in "general engineering" have not prospered in the face of this movement toward specialization. Undoubtedly the desires of students, teachers, practitioners and employers have all contributed in some measure to the rise of specialization, as well as the great expansion of engineering knowledge, and it is significant to note the turn of contemporary opinion away from early and extensive specialization for undergraduate students.[1]

Evolution in Particular Subject Groups.—A second series of charts portrays the evolutionary trends in particular subject groups. The identity and magnitude of the requirements in the several curricula are indicated by a group of distinct bands with abbreviated designations. A common base line is used for two subject groups in a number of cases where the sums of the two sets of related items are significant. In Fig. 10, which deals with the specific subjects in engineering, the item of shop work is added above the mechanical engineering subjects proper to give a more adequate indication of the relative degree of concentration in the mechanical engineering curriculum.

A striking reduction in the total linguistic requirements since 1870 is indicated in Fig. 7. The requirements in *English* quickly fell away from the generous quota of early years under the pressure of the fast-rising technical requirements, then recovered strength, became stabilized, and made slow advances. The *foreign languages* have made a steadily losing fight for recognition over the entire period. As pointed out elsewhere this decline reflects a progressive loss of their tool value as the English language has advanced to its present dominating position in scientific and technical literature. The battle for the continued existence of foreign languages as a requirement will probably be fought largely on the ground of their cultural, commercial and political values, and it is a question whether this issue has yet been seriously faced.

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[1] See Bulletin No. 9 of this series.

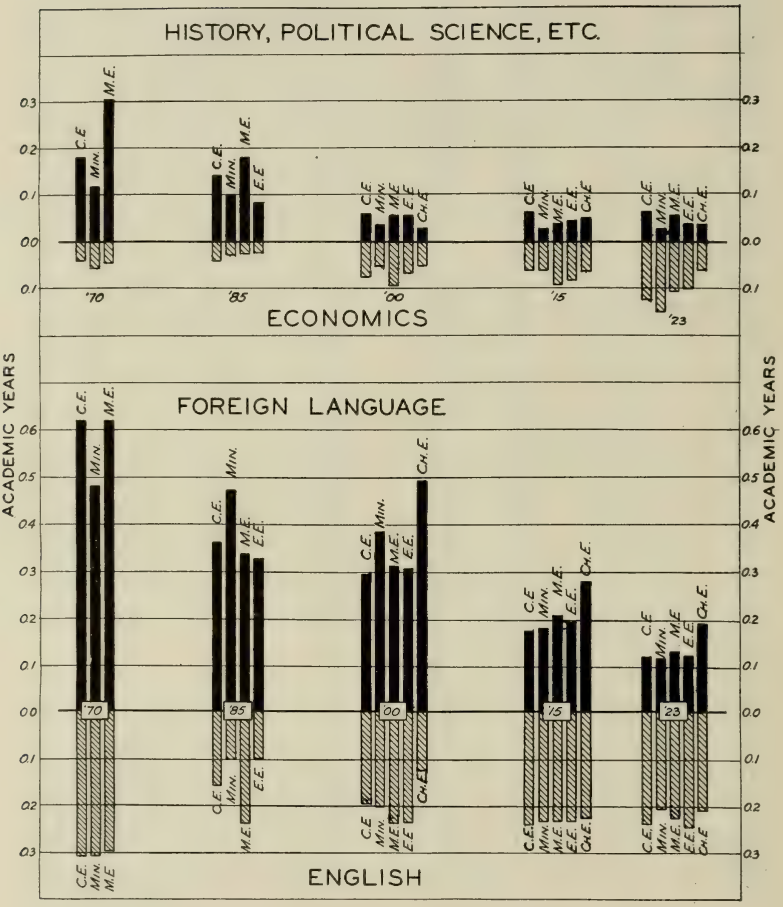

FIG. 7. Changes in social and language studies in engineering curricula.

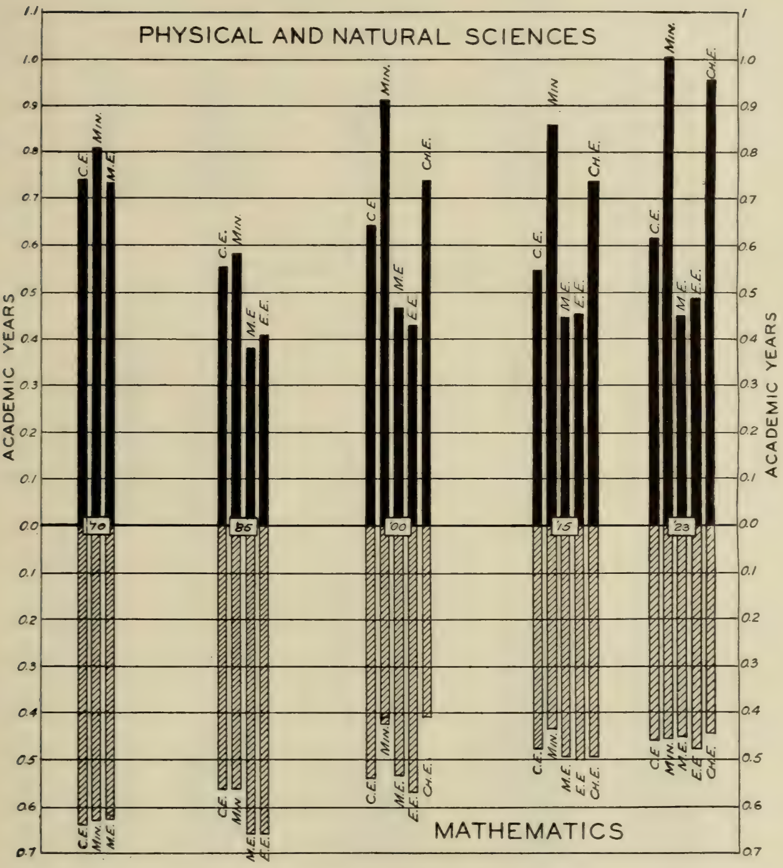

FIG. 8. Changes in requirements in mathematics and physical sciences.

(Note: Additional chemistry is included in chemical engineering curriculum.)

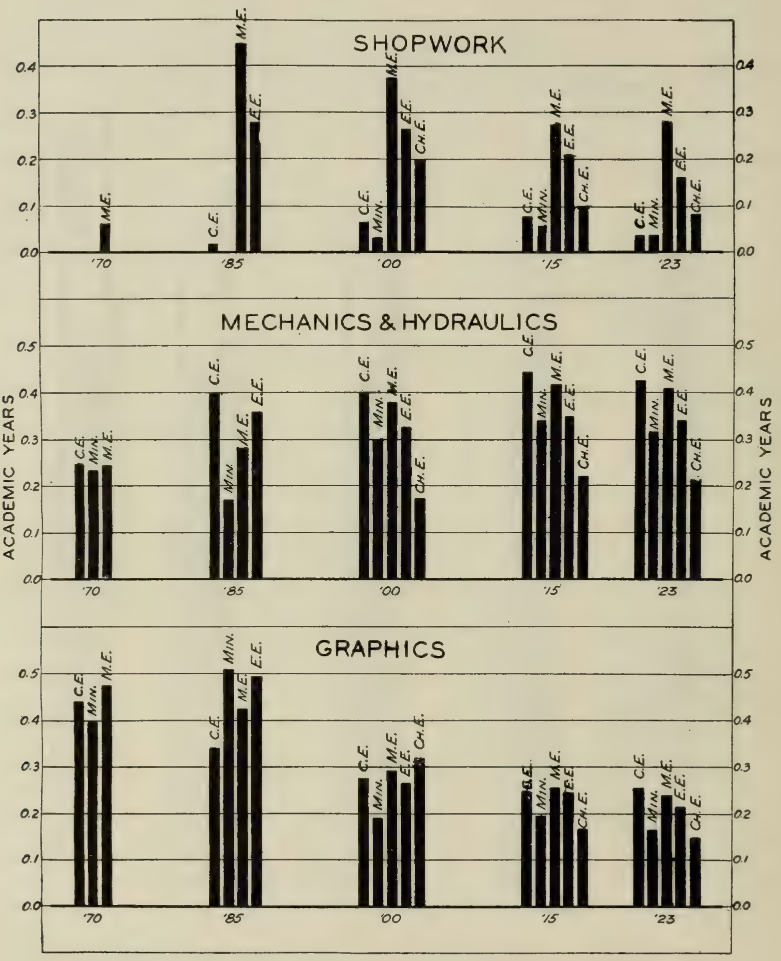

FIG. 9. Changes in requirements in general technical subjects.

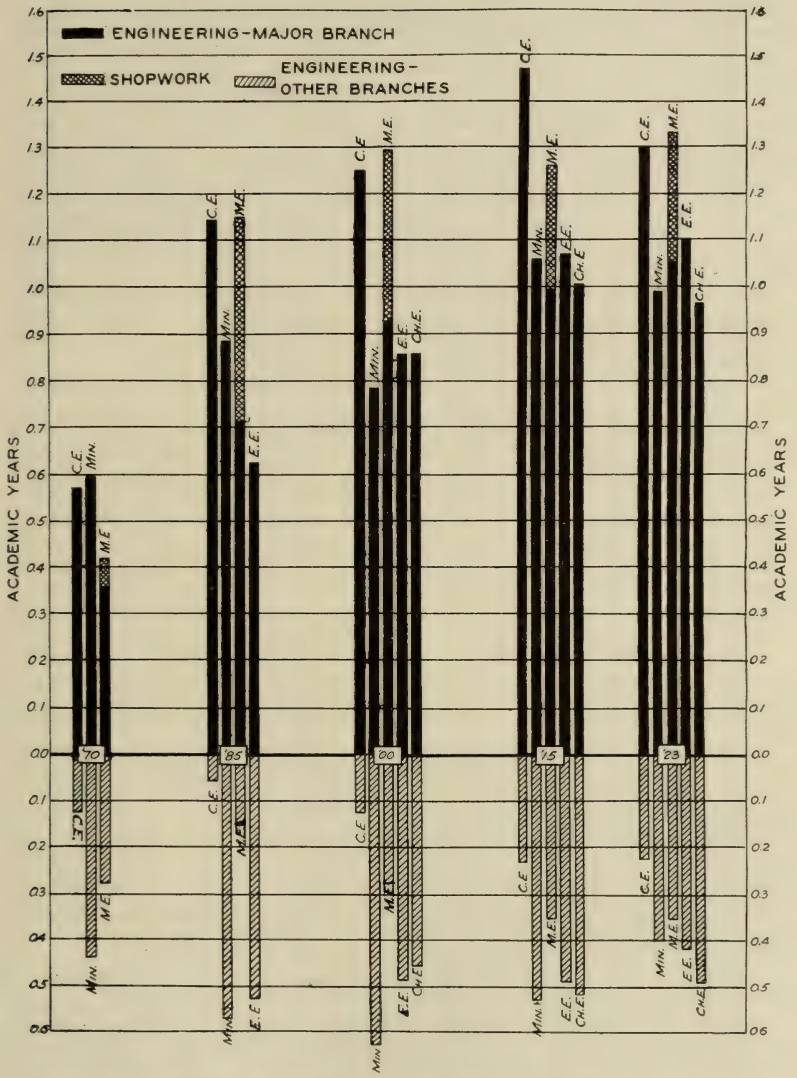

FIG. 10. Changes in requirements in specific engineering subjects.

It is apparent that English has gained little from the decline of the foreign languages and that most of the time released has been absorbed by the specific engineering subjects.

In the group of *social studies* economics has grown in importance at the expense of its kindred. The latter, however, have had some compensation in the growth of free electives. There is no indication that economics has been regarded by curriculum makers as a foundation subject comparable to mathematics and the physical sciences. With the broader conception of the engineer's function in industry and in public life which is coming to prevail, a new attitude toward economics and derived subjects is developing.

The *general technical groups* give evidence of the declining position of shop work and graphics and the rising strength of mechanics and hydraulics. There has doubtless been some transfer of time and content from graphics to specific engineering subjects, but it seems apparent that the emphasis given to manual arts has been steadily declining, with a corresponding gain in emphasis on the analytical side of engineering. This change of emphasis reflects in some measure the gradual assimilation to university standards of a considerable group of present-day engineering colleges which had their origins as semi-collegiate schools of agriculture and mechanic arts giving particular emphasis to manual training. In Fig. 8 there are indications of a reduction in *mathematical content* and an increase in the *physical* and *natural sciences,* the latter trend being notable in the mining and chemical engineering curricula. There is little to indicate that there has been any appreciable decline in the gross mathematical requirements for entrance and graduation.

The charts give no adequate indication of the trend of evolution with regard to *elective studies,* since only the free electives are shown as a distinct group. General indications point to increasing latitude of election in recent years, although engineering curricula in general remain largely on a prescribed basis. One of the striking features of this series of figures is the increasing degree of concentration on *specific technical subjects* up to 1915, as indicated in Fig. 10. Shop work is shown as a supplementary item to specific subjects in mechanical engineering in order more fully to bring out such concentration in that curriculum.

Are the Data Representative?—It should be understood that this is a study of the curricula of ten representative institutions, rather than a study of the ten most representative or influential models in each field of engineering. It is true, however, that the group of institutions chosen is of more than average prominence and strength and that a number of them have exercised a strong influence over the younger colleges. Possibly the cases chosen represent the dominant influences in mining engineering education somewhat less adequately than in the other fields.

An objective check on the degree to which the data of this study are representative of the general state may be had by comparing certain items from this study with the average results for the country at large as set forth in the comprehensive survey by Dr. W. C. John of the United States Bureau of Education, Bulletin No. 10 of this series. Significant items from the two studies are shown side by side in the following table. The value given in each case represents the percentage of the entire requirements of the curriculum under the given head, in the average case in 1923–24. The columns which

COMPARISONS OF AVERAGE TIME ALLOTMENTS IN 1923–24

(All items are percentages)

Subject Groups	Engineering Curriculum									
	Civil		Mining		Mechanical		Electrical		Chemical	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Engineering, major branch	31.1	29.9	24.2	23.9	26.4	29.6	27.2	24.5	23.7	26.2
Total required engineering	53.4	55.9	46.8	48.7	58.0	57.7	55.2	56.7	46.3	50.6
Mathematics	10.9	11.9	11.1	10.8	11.1	12.1	11.9	12.3	10.8	11.7
Physical sciences	14.6	15.4	25.0	25.6	11.0	13.6	12.0	14.0	23.4	20.6
Social sciences	4.5	3.3	4.4	3.1	4.0	3.4	3.5	3.7	2.5	2.7
English	5.6	6.2	5.1	5.2	5.5	6.2	6.1	6.1	4.9	2.8
Foreign languages	2.9	1.8	2.9	1.2	3.3	1.4	3.0	1.9	4.8	2.8
Physical and military training	3.5	3.7	3.8	3.6	3.6	4.1	3.6	3.6	3.8	3.3

relate to the present study are headed by an (A) and those based on the studies of the Bureau of Education by a (B). Allowing for the fact that the two analyses were made independently, with possibilities of minor differences in classification and in weighting the time allotments, and that elective items were handled differently, the two sets of data are in substantial conformity. The greatest relative disparity is in the foreign language requirements. Apparently the institutions covered by this study are more generous toward this division of work than engineering colleges in general. Probably their entrance requirements are somewhat above the average, as indicated by the lower requirements in mathematics in their curricula. On the whole it seems to be a fair inference that, if present conditions may be taken as an index of what has existed in the past, the data of this study may be accepted as reasonably representative of conditions in general.

Limitations of the Analyses.—The method of analysis employed has two important limitations; it gives no indication of the increase in the total requirements in engineering curricula between 1870 and 1923; and it affords no basis for the comparison of the volume of requirements in engineering and non-engineering curricula.

Total Requirements of 1870 and of Today.—The measurement of requirements for entrance and for graduation in credit units is a relatively recent innovation. Comparatively few college catalogs of the period from 1870 to 1875 give data which can be translated into such units with reasonable certainty, but such comparisons as can be made indicate that the arts curricula of that period represented from 120 to 128 semester-hours, as at present. In some institutions, e.g., Lehigh, equal requirements were set in engineering, while in some others, e.g., Wisconsin, the practical exercises in field work and drawing represented an increment to the usual quota of academic work. The evidence indicates that the total requirements in arts curricula have remained sensibly constant, but that a steadily increasing load was introduced into engineering curricula up to about 1900 and that there has been a slight easing up since that time. The engineering curricula of today, as analyzed by Dr. W. C. John in Bulletin No. 10 of this series, represent a median requirement of close to 145 semester-hours. All facts considered, it would seem safe to infer that the total requirements included in an engineering curriculum of four years have risen fifteen to twenty per cent, on the average, in the period covered by this study.

From the nature of the entrance requirements of 1870, it would seem that practically one year less of preparation, on the average, was required then than now. The required subjects were fewer and the mathematics less extended. Concerning the quality of instruction and the thoroughness of students' work, no conclusive evidence can be found. When both the higher level of entrance and the larger content of the curricula themselves are considered, it seems safe to conclude that the final level of attainment to which present-day programs are directed is certainly more than one year, and probably nearly two, in advance of the standards of 1870.

PART III. OUTLINE OF THE EVOLUTIONARY PROCESS

Early Developments.—The year 1870 was chosen as a point of departure for these studies because it may be said to mark the transition from the pioneer era in American engineering education to an era of rapid growth and consistent development. It will be recalled that the Military Academy at West Point had served as the principal source of formal training for engineers prior to the founding of Rensselaer Polytechnic Institute in 1824. Rensselaer revised its curriculum and added a distinct civil engineering course in 1829; its first engineering degrees were conferred in 1835; and in 1849 it remodelled its program on the lines of the leading French technical schools, increasing the time requirements from one to three years. The Lawrence Scientific School was established at Harvard and the Sheffield Scientific School at Yale in 1847. The University of Michigan pioneered in engineering instruction in the West, offering its first courses in 1853 and awarding its first degrees in engineering in 1860. The Morrill Land Grant Act of 1862 was an event of far-reaching influence. The founding of the School of Mines at Columbia in 1864, the opening of the Massachusetts Institute of Technology in 1865, the establishment of the Thayer School of Civil Engineering at Dartmouth and the founding of Cornell University in 1867, the beginnings of Worcester Polytechnic Institute with its distinctive scheme of shop training by actual production in 1868, and the opening of the first laboratory for class instruction in physics at Massachusetts Institute in 1869, were all notable milestones in the early progress of engineering education in America.

In 1866 there were but six engineering colleges of established reputation and but 300 men had been graduated in the previous thirty-one years. By 1870 the indications of growth were considerable; twelve states had accepted the provisions of the Morrill Act; the total number of engineering colleges had mounted to twenty-one and the number of engineers graduated to 866. From its founding in 1852 until 1871 the American Society of Civil Engineers was virtually the only national organization of engineers. The present profession of engineering was still a single stem in 1870, but with budding indications of a branching growth. The Northern and Western states were in the full swing of a vast process of industrial expansion, railroad building, city development and land settlement which marked the economic rebound from the Civil War and greatly stimulated the demand for engineering services. In the older states of the East the transition from an agricultural era to an industrial era gave a strong impetus to the subdivision and specialization of the engineering profession. A half century of delay in the economic recovery of the South made the progress of engineering education in that region slow and difficult until the last two decades.

In the period leading up to 1870 science was struggling its way with difficulty to a place of freedom and equality in the educational scheme. The scant sufferance extended to science in Eastern institutions with deeply rooted classical traditions made it necessary for applied science to seek a home with adequate resources and scope for development in independent ''institutes,'' which did much to invest engineering education with its distinctive qualities and its traditional rigor. The newer institutions founded by the fast-developing states of the Middle West had a new conception back of them; they were to be instruments of social change no less than seats of learning. Naturally, applied science found them hospitable from the beginning and developed its program on collegiate lines.

Early Educational Processes.—Fletcher has pictured the state of engineering education prior to 1870 as follows:[1]

> "The schools had very inadequate resources; engineering laboratories for general instruction were practically unknown, although here and there a professor was improvising experiments on a small scale; text-books were few and many derived from abroad; instruction was probably more largely by recitation from the book, with great emphasis on purely mathematical exposition; . . . the subjects taught were much the same by name as those taught today (*i.e.*, in civil engineering in 1896), but not so many, nor as practically developed, and without aids now deemed essential; they were, however, fundamental and the capable student got a firm grasp of principles."

In another address the same writer continued:[2]

> "The great masters of mathematical exposition set a fashion of teaching which was criticized as too severe and impractical. School facilities being inadequate, and class laboratories almost unknown, the results of experimental research were dressed in mathematics and taught largely through the 'weight of authority' from the book; and while the instructor performed elementary experiments on the other side of the table, the class simply 'observed' and perhaps tried to 'take notes.'"

In his presidential address before the Society for the Promotion of Engineering Education in 1896 Mansfield Merriman threw further light on the teaching of this period:[3]

> "Thirty years ago public opinion looked with distrust on technical education. Its scientific basis and utilitarian aims were regarded as on a far lower plane than classical education. . . . Engineering courses a quarter of a century ago were scientific rather than technical. It was recognized that the principles and facts of science were likely to be useful in the

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[1] *Proceedings,* S. P. E. E., Vol. IV, 1896, p. 31 et seq.

[2] Trans. Int. Eng. Congress, included in *Trans. A. S. C. E.,* Vol. 54A, 1905, p. 455.

[3] *Proceedings,* S. P. E. E., Vol. IV, 1896, p. 16.

> every-day work of life and particularly in the design and construction of machinery and structures. Hence mathematics was taught more thoroughly and with greater regard to practical applications, chemistry and physics were exemplified by laboratory work, drawing was introduced and surveying was taught by actual field practice. Although engineering practice was rarely discussed in those early schools, and although questions of economic construction were but seldom brought to the attention of students, yet the scientific spirit that prevailed was most praiseworthy and its influence has been far-reaching.
>
> ''This scientific education notably differed from the old classical education in two important respects: first, the principles of science were regarded as principles of truth whose study was ennobling because it attempted to solve the mystery of the universe; and second, the laws of the forces of nature were recognized as important to be understood in order to advance the prosperity and happiness of man. The former point of view led to the introduction of experimental work, it being recognized that the truth of nature's laws could be verified by experience alone; the latter point of view led to the application of these laws in industrial and technical experimentation. Gradually the latter tendency became far stronger than the former, and thus the scientific school developed into the engineering college.''

Contrasts in Evolution of Engineering and Other Professional Curricula.—The engineering curricula of 1870 were obviously derived from collegiate models as variants to the then existing curricula in modern sciences and languages, with modifications as pointed out by Merriman in the passage quoted above. Their origins and evolution were in quite the reverse direction to the course taken in the development of legal, medical and dental education. Formal education for these professions grew directly out of apprenticeship; it was initiated and conducted by practitioners, almost wholly on a proprietary basis, and it began on a purely practical and technical plane with none of the general qualities of collegiate education. Engineering education in America, practically from its inception, was in all essential respects a form of collegiate education; it was instituted and directed by educators rather than practitioners; it did not evolve from apprenticeship and only slowly and partially replaced it; it was never on a proprietary basis; and it gained the patronage and support of practitioners with considerable struggle.

The dominant place given to purely general subjects in these early curricula points strongly to extensive borrowing from the collegiate curricula in modern branches and to the paucity of specific materials for engineering instruction. The large time allotment to foreign languages was plainly caused by the scarcity of treatises and texts in the English language and by the dependence of the student on French and German publications. There is little to suggest that these languages were studied primarily for their humanistic and commercial values; they were necessary tools; as time brought an increased output of suitable publication in English the need for such tools decreased and they were given proportionately less emphasis. The time devoted to English and to social studies is probably the best index to the cultural qualities of the early curricula.

Developments from 1870 to 1885.—This was the great formative epoch in American engineering education. The collegiate type of curriculum, with its extended base of science, mathematics, languages and social studies, though modified by the pressure of expanding engineering knowledge and technique, proved its stability and became firmly established as the basic process in American engineering education. The Centennial Exposition of 1876 did much to popularize and stimulate technical education. The attention of leading educators, notably President Runkle of the Massachusetts Institute of Technology, was attracted by the exhibit of the methods and products of a system of manual training which had been developed in Russia. A strong impetus was given to the introduction of similar methods of training, both in engineering colleges and in secondary schools. By 1885 shop work had attained its maximum position in engineering curricula, as measured by time allotment, and considerably overshadowed the emphasis on laboratory instruction in the engineering branches. Laboratory teaching of the physical sciences, however, was greatly extended in this period and substantial progress made in developing laboratories of engineering. The University of Michigan established the first summer camp for instruction in surveying in 1874. Apparently this example stood alone for twenty years, more or less, after which this plan of teaching became quite general in civil engineering curricula.

The period between 1870 and 1885 was marked by the expansion and diversification of the engineering profession, as indicated by the founding of the American Institute of Mining and Metallurgical Engineers in 1871, the American Society of Mechanical Engineers in 1880, and the American Institute of Electrical Engineers in 1884. Similar influences were at work in the colleges and it was in this period that the basic scheme of differentiated curricula in the major technical branches of engineering became firmly established. The expansion of mechanical engineering education in this period was especially notable. Toward the end of the period the foundations of distinct curricula in electrical engineering were laid at Massachusetts Institute and at Cornell. In both instances the new curriculum developed under the fostering of the department of physics, a further striking indication that engineering curricula evolved from the scientific toward the technical, rather than in the reverse direction as in other branches of professional education. Fifteen years later these evolutionary steps were repeated in the growth of distinct curricula in chemical engineering.

The provisions of the Land Grant Act of 1862 were widely adopted by the states during this period, resulting in a rapid growth in the number of engineering colleges. The conspicuous models set by Rensselaer, Michigan, Massachusetts Institute and Cornell were widely copied in these newer institutions. The early results, to be sure, were often but remote approximations to the models chosen, but the effect in the long run has been sound. Standardization by imitation has manifest limitations, but it has probably saved engineering education from any considerable admixture of shoddy.

Of all the elements of progress in this period, possibly first rank should be given to the beginnings of an epoch of notable teaching and authorship by Merriman, Fuertes, DeVolson Wood, Thurston, Johnson, and others. American engineering education turned definitely from European models and sources to seek its leadership and materials on its own fertile ground.

Developments from 1885 to 1900.—It is in this period that engineering education in America may be said to have come into its own. Great industrial expansion and notable progress in invention caught the popular imagination. Education in applied science grew in popularity to a point where it seemed to threaten not merely the preeminence but even the actual existence of classical culture for young men. The number of engineering colleges grew with great rapidity, both through the operations of the Land Grant Act and through private benefactions. By 1896 the number of such institutions had risen to 110.

Much of this expansion took place on a fairly low academic level. A classification of engineering colleges with reference to their entrance requirements, made in 1896, showed the following grouping:[1]

Class A, 31 colleges; requiring for entrance at least algebra through quadratics, plane geometry, solid geometry or plane trigonometry, one year of foreign language, and moderately high requirements in English.

Class B, 33 colleges; requiring algebra through quadratics and plane geometry.

Class C, 25 colleges; requiring less than algebra through quadratics and plane trigonometry.

Class D, 18 colleges; not offering complete courses in engineering, but giving analagous work, generally under the head of mechanic arts; many in process of developing into true engineering colleges.

Class E, 3 colleges; having no entrance requirements as such, but doing engineering work of good grade.

The lax requirements of many engineering colleges at this period (1896) as compared with the old-line classical colleges were regarded by the better grade of preparatory schools as a demoralizing influence and led to many complaints.

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[1] *Proceedings*, S. P. E. E., Vol. III, 1895, p. 25 et seq., and Vol. IV, 1896, p. 101 et seq.

One of the most significant events in the period under consideration was the formation of the Society for the Promotion of Engineering Education in 1893. It promptly drew to itself the leading spirits in engineering education. Its early rosters of officers and members give evidence of the dominant influence of a small group of notable institutions with sound standards and progressive policies. Beyond question the moral influence of this organization was a primary force in preserving the norm of high scholastic standards and the ideal of a relatively liberal, collegiate type of curriculum.

It was in this period, more than any other, that the laboratory method of instruction in engineering branches grew to its dominating position. This change was due in part to the rise in importance of mechanical and electrical engineering. Early curricula had been dominated largely by the model of civil engineering, with its emphasis on design and field work. The early civil engineering curricula in their turn had been largely influenced, directly and indirectly, by French models characterized by an emphasis on didactic methods of instruction and on mathematical and analytical, rather than experimental methods of attack. By 1900 it was generally recognized that American laboratory installations and methods for the teaching of engineering were not surpassed and not often equalled in any other part of the world. As much could not rightfully be claimed, however, for much of the theoretical instruction and especially for instruction in design.

Among the specific changes in curricula between 1885 and 1900 may be noted the distinct recovery of ground by the physical sciences, the progressive transfer of elementary mathematics from college curricula to entrance requirements, the reduction of time given to drawing and shop work as distinct subjects in favor of the engineering subjects as such, the diminished emphasis on foreign languages in consequence of the rapid growth of an indigenous engineering literature and the pressure of increasing technical specialization, the recovery of ground by English and the emergence of economics to a place of prominence among the group of social sciences. The beginnings of chemical engineering as a distinct curriculum marked the end of the period.

Developments since 1900.—The first decade of the century saw engineering education in America reach the climax of its popularity relative to other major divisions of higher education. As the second decade developed agricultural education sprang into prominence and as it closed collegiate education for business was in a rapid upswing. These developments somewhat checked the expansion of engineering education and probably for its good. The events of the World War, however, served to direct attention to engineering education anew. The prominent place gained by engineers in the direction of industry, the notable contributions of engineering to the technique of production, and the conspicuous place taken by engineers in war activities, led to a marked increase of emphasis on the administrative and economic side of engineering.

The influence of this march of events on engineering curricula is apparent. Distinct curricula to emphasize the administrative rather than the technical aspects of engineering were introduced rather widely. The place given to economics in all curricula was augmented, often at the expense of time previously given to other social subjects. Business electives in engineering curricula were more widely provided. Since the war there has been a discernible trend away from specialization for undergraduates. The effort to stretch a four-year college program into an all-round or a specialized training is being frankly abandoned, with a reaction toward simplification of programs and a greater emphasis on general training.

Cooperative Plan.[1]—The development of the cooperative method of engineering education, based on alternate periods of instruction in college and of experience in engineering works and industries, has been a prominent feature of this period.

Part-time education, combined with productive employment, had been in operation in both Europe and America for well over one hundred years but the plan instituted at the University of Cincinnati in 1906 was new in so far as it involved the pairing of students, and their wide distribution in industry under the alternating plan. Similar plans have since been adopted in greater or less degree in nearly one-eighth of the engineering colleges of the United States, and have attained a secure and stable position. There are now seven institutions which use this method exclusively, throughout all stages of their curricula, and six others require it in certain years of all their programs. In five other cases the method is employed as an alternative to the usual all-resident plan. When given the benefit of equally strong personnel and ample facilities, the cooperative plan is quite generally accepted as a worthy alternative to the all-resident plan in combination with part of the usual industrial or professional apprenticeship. It has certain economic advantages and leads to certain administrative complications. What unique merits it may claim, judged purely as an educational process, and what distinctive type of product it leads to, are not yet adequately determined.

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[1] For more complete discussion see Bulletin No. 12.

Characteristics of Present Curricula.—Engineering curricula, in their more essential qualities, are to-day what they were fifty years ago—a distinctive type of college program based primarily on the principles and applications of physical sciences and mathematics, with associated studies in languages and social sciences, and intended to precede and supplement, but not supplant, an extended professional apprenticeship. College training is assumed to provide the more general, and apprenticeship the more specific, preparation for an engineering career. The numerous changes of detail in the course of fifty years do not invalidate this characterization.

A high degree of structural unity has always been a striking characteristic of engineering curricula. There are close-knit, logical sequences of subject matter running from beginning to end with a fairly intimate coordination of detail between the separate subjects. Few subjects in the curriculum are treated in an wholly discrete manner. The tendency is to plan the curriculum with a view to the whole which is something more than the mere aggregate of its parts. While it is impossible to speak with finality, there are indications that present curricula are closer knit, in a formal sense, than those of earlier years; on the other hand, loss of intimacy between individual teachers and departments, due to expansion and subdivision of organization, has worked against the desired coordination.

The striking stability of the broader features of these curricula throughout a half century of revolutionary changes in other realms of higher education may be ascribed either to stubborn conservatism or to the fundamental soundness of engineering programs, according to the view-point of the individual. The latter seems to be much the more reasonable alternative. There are few if any branches of higher education which are more severely tested by objective realities, nor are there any in which the content of curricula is more constantly and critically scrutinized for its relevancy, in consequence of the rapid advance of knowledge and technical practice and the enforced limitations of time. The testimony of graduates, practitioners and employers gives ample support to the fundamental soundness of engineering education in its general plan, while indicating the need of many betterments of detail.

Are Present Curricula Illiberal?—There is a tendency among some educationists to characterize engineering education as narrow, specialized and illiberal. It is impossible to say how largely these assertions are based on informed judgment and how largely on vague impressions arising from the contrast between an integral curriculum combining general and technical training and the tandem plan of distinct preprofessional and technical stages which has been developed in legal, medical and dental education. Excluding physical and military training, engineering curricula may be subdivided into five principal divisions, as in the following table:

PRINCIPAL GROUP REQUIREMENTS IN ENGINEERING CURRICULA, EXPRESSED IN ACADEMIC YEARS

	1870	1885	1900	1915	1923
Humanistic	1.137	.706	.653	.560	.516
Scientific	1.385	1.091	1.094	1.065	1.127
Free electives	.026	.059	.048	.084	.151
General technology	.939	1.143	1.173	1.136	1.068
Special technology	.509	.882	.965	1.122	1.095

In the face of the above facts it can not be asserted that engineering curricula have become more liberal as a result of evolution. The peak of specialization has apparently been reached and passed, there has been a gain in scientific content and emphasis, and opportunity for free election has been increased, but the prescribed humanistic content has decreased. This decrease has resulted principally from the decline in foreign language requirements, and since 1885 entirely so. The low valuation placed by many graduates on their training in foreign language suggests that the indicated loss in humanistic content over the whole period has been more apparent than real. It would seem, however, that a larger compensatory gain in English and social studies, or in free electives, might reasonably have been expected.

The increase of technical specialization has also probably been more apparent than real, when it is considered that time transferred from physical sciences to engineering subjects is by no means lost to scientific culture, that the reduced time devoted to mathematics has been fully offset by gains in average entrance requirements, and that the growth of time given to technical engineering subjects has been primarily at the expense of graphics and shop work, and secondarily at the expense of foreign languages formerly studied as necessary keys to foreign technical literature.

When all reasonable allowances have been made for compensating elements not appearing on the face of the data, it still remains true that the trend of evolution up to 1915 was away from a broad educational emphasis and toward a specialized training. Since that date there has been a perceptible trend toward broader educational ideals and programs.

Comparison of General Content with Pre-professional Curricula.—The generalized picture of engineering curricula given in Fig. 11 makes it apparent that practically 1.8 academic years of general training which would be entirely acceptable toward a degree in arts are included. It should be recalled that the unit academic year refers strictly to prevailing requirements in engineering colleges, which are generally from twenty to twenty-five per cent greater in volume than those of a typical arts college for an equal period. It is therefore conservative to state that the average engineering curriculum includes the equivalent of more than two years formal training in a college of liberal arts.[1] The collegiate work prescribed for admission to Class A schools of law and medicine is two years, and a like requirement is being put into effect in dentistry. There is a significant difference behind the apparent equality of these pre-technical educational requirements, namely, that a much higher proportion of such work prescribed for engineers bears an organic relation to the technical studies which follow.

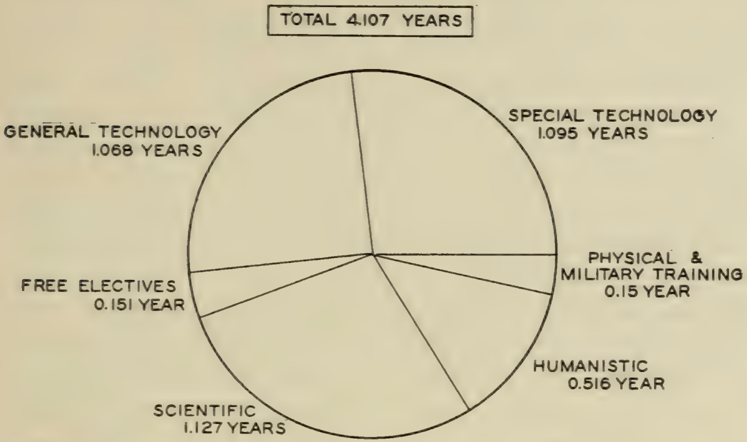

FIG. 11. Major divisions of the composite engineering curriculum of 1923–24.

Considering both phases of training, the general and the technical, the engineering student gets as much general training as is required of the student of law or medicine, but is confined within a narrow range of choice which permits less emphasis on distinctly humanistic subjects; he gets less technical training in college and has greater occasion to extend his training through apprenticeship and post-scholastic study. It should be noted, however, that two-thirds of the students entering the technical study of medicine hold college degrees or are to receive them in an additional year of a combined program, and that a considerable number of the stronger medical schools admit only such students. There is a similar tendency in legal education, though less advanced at present. Less than ten per cent of the students admitted to engineering colleges hold collegiate degrees.

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[1] For confirmations see Bulletin No. 10 of this series, p. 441.

General Qualities of Undergraduate Engineering Curricula.—Engineering curricula aim to provide a thorough grounding in the principles of science and the methods of engineering, together with elements of liberal culture intended to enrich the personal life of the student and fit him for a worthy place in human society. They do not afford a complete professional training. Whatever their original purpose, the majority of engineering graduates actually put their training to the uses of a general education. These curricula should therefore be appraised as a type of college training, aiming at large general values and intended to lay only the broader rather than the specialized foundations for a professional career. They draw on many fields of knowledge, but not at random. They bring the selected elements to a common focus in a distinctive field of technical activity. What they lack in freedom for a wide ranging over the whole area of human thought must be weighed against the values inherent in organized and directed effort under circumstances favorable to strong motivation. The present trend of evolution is toward a greater emphasis on general, rather than technical, educational values in undergraduate college work, and toward the more extended development of supplementary stages of specialized training in the early years after graduation.

PART IV. TABLES OF DATA

1. Cases Included in the Analyses of Engineering Curricula

	Alabama Polytechnic	Case	Cornell	Illinois	Iowa State College	Lehigh	Mass. Inst. Tech.	Michigan	Purdue	Wisconsin
Civil Engineering:										
1870					×	×	×	×	×	×
1885			×		×	×	×	×	×	×
1900		×	×	×	×	×	×	×	×	×
1915	×	×	×	×	×	×	×	×	×	×
1923	×	×	×	×	×	×	×	×	×	×
Mining Engineering:										
1870					×	×	×			×
1885						×	×			×
1900		×			×	×	×			
1915		×		×	×	×	×			×
1923		×		×	×	×	×			×
Mechanical Engineering:										
1870					×	×	×	×	×	
1885	×		×		×	×	×	×	×	×
1900	×	×	×	×	×	×	×	×	×	×
1915	×	×	×	×	×	×	×	×	×	×
1923	×	×	×	×	×	×	×	×	×	×
Electrical Engineering:										
1885			×				×			
1900	×	×	×	×	×	×	×	×	×	×
1915	×	×	×	×	×	×	×	×	×	×
1923	×	×	×	×	×	×	×	×	×	×
Chemical Engineering:										
1900				×			×	×		
1915	×	×		×	×	×	×	×	×	×
1923	×	×		×	×	×	×	×	×	×

2. Composite Results of Analyses of Engineering Curricula

Curriculum	Year	Number of Cases	Engineering—Major Branch	Engineering—Other Branches	Mechanics and Hydraulics	Graphics	Shop Work	Free Electives	Physical Sciences	Mathematics	Economics	Other Social Sciences	English	Foreign Languages	Physical and Military Training
Civil Eng.	1870	6	.576	.124	.240	.437	.000	.066	.739	.636	.042	.182	.302	.621	.043
	1885	7	1.145	.059	.393	.338	.016	.110	.566	.567	.041	.136	.159	.356	.125
	1900	9	1.248	.134	.398	.273	.060	.054	.640	.540	.076	.053	.194	.295	.084
	1915	10	1.465	.231	.441	.242	.074	.082	.548	.477	.062	.064	.235	.172	.147
	1923	10	1.300	.226	.426	.252	.032	.187	.613	.453	.123	.066	.234	.122	.148
Mining Eng.	1870	4	.596	.441	.230	.397	.000	.000	.809	.627	.062	.116	.309	.476	.064
	1885	3	.884	.572	.169	.512	.000	.000	.582	.565	.024	.100	.099	.473	.172
	1900	4	.781	.630	.298	.188	.025	.000	.912	.428	.049	.035	.203	.388	.052
	1915	6	1.059	.525	.340	.195	.051	.071	.858	.435	.062	.027	.227	.182	.177
	1923	6	.990	.400	.316	.168	.032	.040	1.020	.454	.151	.027	.208	.120	.155
Mech. Eng.	1870	5	.360	.279	.239	.471	.061	.000	.731	.624	.049	.305	.289	.623	.034
	1885	8	.712	.149	.279	.424	.447	.050	.377	.662	.023	.176	.243	.330	.104
	1900	10	.925	.274	.379	.288	.369	.048	.464	.538	.059	.052	.236	.317	.095
	1915	10	.997	.347	.416	.257	.271	.100	.449	.493	.099	.041	.235	.204	.154
	1923	10	1.065	.355	.407	.239	.273	.139	.444	.449	.104	.056	.223	.132	.147
Elec. Eng.	1885	2	.634	.527	.356	.494	.275	.000	.409	.662	.021	.082	.087	.328	.125
	1900	10	.856	.486	.325	.262	.265	.044	.427	.570	.066	.051	.235	.305	.104
	1915	10	1.067	.491	.343	.246	.205	.053	.453	.499	.083	.043	.233	.193	.154
	1923	10	1.100	.417	.341	.215	.159	.199	.487	.481	.100	.040	.245	.121	.146
Chem. Eng.	1900	3	.858	.466	.163	.300	.198	.107	.738	.405	.042	.026	.121	.494	.075
	1915	9	1.014	.514	.216	.167	.084	.111	.732	.488	.061	.053	.221	.281	.161
	1923	9	.967	.488	.210	.146	.078	.144	.959	.441	.060	.040	.202	.197	.154

3. GENERAL COMPOSITE ANALYSES OF COMBINED CURRICULA

Curriculum	Year	Number of Cases	Engineering—Major Branch	Engineering—Other Branches	Mechanics and Hydraulics	Graphics	Shop Work	Free Electives	Physical Sciences	Mathematics	Economics	Other Social Sciences	English	Foreign Languages	Physical and Military Training
Composite of all curricula	1870	15	.509	.260	.237	.438	.020	.026	.755	.630	.050	.205	.299	.583	.046
	1885	20	.882	.219	.310	.414	.212	.059	.477	.614	.029	.141	.176	.360	.124
	1900	36	.965	.353	.342	.267	.211	.048	.570	.524	.063	.047	.212	.331	.088
	1915	45	1.122	.410	.355	.225	.146	.084	.583	.482	.075	.047	.231	.207	.157
	1923	45	1.095	.373	.362	.208	.123	.151	.671	.456	.105	.048	.224	.139	.150

4. AMOUNTS AND PERCENTAGES OF PRINCIPAL GROUP TOTALS IN THE GENERAL COMPOSITE RESULTS

Year	Number of Cases	Total Academic Years	Total—Specific Engineering Subjects		Total—Prescribed Technical Subjects		Total—Prescr. Tech. Subjects and Free Electives		Total—Mathematics and Physical Science		Total—Language and Social Sciences		Total—Non-technical Subjects		Total—Non-tech. Subjects and Free Electives	
			Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%	Amt.	%
1870	15	4.042	.769	19.0	1.448	35.8	1.474	36.5	1.385	34.3	1.137	28.1	2.568	63.5	2.594	64.1
1885	20	4.017	1.101	27.4	2.037	50.8	2.096	52.3	1.091	27.2	.706	17.6	1.921	47.9	1.980	49.3
1900	36	4.021	1.318	32.8	2.138	53.1	2.186	54.4	1.094	27.2	.653	16.2	1.835	45.6	1.883	46.8
1915	45	4.124	1.532	37.1	2.258	54.7	2.342	56.8	1.065	25.8	.560	13.6	1.782	43.2	1.866	45.2
1923	45	4.105	1.468	36.6	2.161	53.9	2.312	57.6	1.127	28.1	.516	12.8	1.793	44.7	1.944	48.4

BULLETIN NUMBER 12
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF THE COOPERATIVE METHOD OF ENGINEERING EDUCATION

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THE COOPERATIVE METHOD OF ENGINEERING EDUCATION

Purposes.—In the twenty years since its establishment at the University of Cincinnati, the cooperative method has passed through an initial stage of trial and experimentation and has now made a permanent place for itself in engineering education. Whatever may be believed of the merits of the plan, its advent appears to constitute one of the major developments in engineering education in the past quarter-century. The time seems ripe to attempt an appraisal of the system.

There has been much discussion of the cooperative plan, both oral and written, since its inception. This has consisted largely of descriptions of the methods of conducting cooperative courses in particular institutions and of opinions of the merits of the system advanced by its advocates. There has been little in the way of a comprehensive summary of the situation or a critical appraisal of values. The purpose of this study is to supply these deficiencies in so far as possible by presenting the important facts relating to cooperative courses; by analyzing those facts in relation both to the methods and to the principles involved; by gathering and weighing opinions of those competent to express themselves; and finally by presenting such conclusions as the facts and opinions seem to warrant.

Scope.—For the purpose of this report the term ''cooperative engineering curriculum'' is applied to a curriculum of predominantly engineering character, leading to a degree, which provides for the alternation at regularly scheduled intervals of periods of instruction in college and of supervised and correlated experience in industry. The study deals only with curricula so defined, and does not include the application of the cooperative principle in other fields of education. This accords, in general, with the limits of the investigation as a whole, and was necessary in order to fix a boundary to the present study. It is probably pertinent to add that the cooperative principle has found more widespread application in engineering than in any other field of higher education.

The study has been divided into four principal divisions as follows:

I. General data concerning cooperative courses,
II. Organization and administration of cooperative courses,
III. Appraisal of value of the cooperative system,
IV. Review of literature on the subject.

Auspices and Methods.—An invitation was extended to the faculty of the Polytechnic Institute of Brooklyn to conduct a study of cooperative engineering training as its contribution to the Society's general investigation. The invitation was cordially accepted and the following committee was appointed to carry on the work:

Erich Hausmann, *Chairman,*
Edwin F. Church, Jr., *Secretary,*
Robin Beach,
Harry P. Hammond,
Clarence W. Hudson,
John C. Olsen,
S. Marion Tucker,
Parke R. Kolbe, ex-officio,
Ernest J. Streubel, ex-officio.

The committee gathered a considerable body of data and opinion relating to cooperative courses. Much of this information was collected by means of questionnaires. Other data were abstracted from official catalogues and confirmed or amplified by correspondence where such step was necessary. Visits were made to a number of representative institutions and numerous conferences were held with persons interested in or familiar with the plan and its results. An extensive search was made of the literature on cooperative courses.

The results of this work were compiled and studied by the committee and a summary was presented by the Chairman as a preliminary report at the annual convention of the Society in June, 1926. Copies of this report are available in limited numbers at the office of the Director of Investigation, Society for the Promotion of Engineering Education, 33 West 39th Street, New York City.

The committee preferred not to submit any statement of its views on the value of cooperative engineering training in connection with the present document, and has therefore confined its report to statements of fact and to quotations of the opinions of others.

The report submitted by the committee has been taken as the basis of data upon which the present document has been prepared by the Staff, as named elsewhere. The facts and opinions compiled by the committee have been incorporated, with certain rearrangements and some additions, in Parts I, II, and IV of the present report. The quotations of opinions as to the advantages and disadvantages of cooperative courses were also compiled largely from material gathered by the committee. All inferences and conclusions in Section D of Part III of this report have been written entirely by the Staff which accepts full responsibility for the statements made. Findings and recommendations of the Board of Investigation and Coordination as to cooperative courses will be included among other recommendations of the Board which will appear separately.

PART I. GENERAL DATA RELATING TO COOPERATIVE COURSES

The combination of practical experience with scholastic training has been advocated as a desirable educational method many times in the past, and several plans for accomplishing this end have been instituted in certain divisions of the general field of education. The so-called ''sandwich plan,'' which provides opportunity for the engineering apprentices of Scottish industries to obtain a technical education by attendance at educational institutions during certain months of the year, is an example of such a plan in the field of engineering education. Cooperative engineering courses as conducted in the United States are, however, a distinctive type of educational program for which little or no direct precedent can be found. It is probably both fitting and accurate to credit not only the inception of the idea of such courses but also the position which the plan occupies in this country at present in large measure to the ability, resourcefulness, courage, and consistency of purpose of Dean Herman Schneider who first established cooperative engineering courses at Cincinnati in 1906.* At that time the cooperative option (all-resident curricula were continued until 1919) was chosen by 27 of the 134 engineering students then enrolled in the institution. Since that time the number of institutions offering such courses has grown from one to sixteen,† and the number of students enrolled under the cooperative plan in 1925–26 was approximately 5,500. As the total number of colleges in the United States which offer curricula in engineering leading to degrees is now between 150 and 160, it is seen that approximately ten per cent of these colleges now offer cooperative courses. The number of students enrolled in cooperative courses is also approximately ten per cent of the total enrollment of engineering students in the country.

Number and Types of Institutions Offering Cooperative Courses.—Table I lists the sixteen institutions which offer one or more engineering curricula on the cooperative plan in which there is any considerable enrollment of students. The table also gives the types of institutions and indicates abbreviations which will be employed for convenience in referring to the institutions in this report.

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* For a more complete statement regarding the inception and development of the plan at the University of Cincinnati see "The Cooperative System of Education" by Clyde W. Park; University of Cincinnati Studies, Series II, Volume XI, Part I.

† Since the original compilation of the data of this report, two additional institutions have announced the establishment of cooperative courses. See also footnote on page 563.

TABLE I *

Name.	Type.	Abbreviation.
Municipal University of Akron	Municipal university	Akron
University of Cincinnati	Municipal university	Cincinnati
Detroit Institute of Technology	Y. M. C. A. institution	Detroit Inst.
University of Detroit	Sectarian university	Detroit Univ.
The Drexel Institute (Philadelphia, Pa.)	Endowed technical college	Drexel
Evansville College (Indiana)	Sectarian college	Evansville
Georgia School of Technology (Atlanta)	State supported polytechnic institute	Georgia
University of Louisville	Municipal university	Louisville
Marquette University (Milwaukee, Wis.)	Sectarian university	Marquette
Massachusetts Institute of Technology (Department of Electrical Engineering) (Cambridge, Mass.)	Endowed polytechnic institute	M. I. T.
New York University	Endowed university	N. Y. U.
Newark Technical School (New Jersey)	Municipally and state controlled college of engineering	Newark
University of North Carolina (Chapel Hill)	State university	No. Carolina
Northeastern University (Boston, Mass.)	Y. M. C. A. institution	Northeastern
University of Pittsburgh	Endowed university	Pittsburgh
Southern Methodist University (Dallas, Texas)	Sectarian university	So. Methodist

* Since the compilation of the above list, the Cleveland Y. M. C. A. School of Technology has increased the length of its cooperative curricula in engineering from three to five years and now confers the degree Bachelor of Science.

The University of Tennessee announces that beginning with the session 1926–27, engineering students may choose either a regular four-year curriculum, or a five-year cooperative curriculum. The first year of the latter will be on the all-resident plan, followed by four years of cooperative training. Alternation between college and industry will be at intervals of the University term of twelve weeks.

Certain institutions and curricula studied by the committee are not included in the above list for reasons set forth in the following notes:

Antioch College offers genuinely cooperative curricula and maintains a department of engineering. Students may elect engineering as their ''field of concentration.'' Complete curricula in engineering are not offered, however, on a basis comparable with those of the sixteen institutions listed. Of a total of 225 term credits required for the degree Bachelor of Science but forty-four are in specified engineering subjects and ten are in engineering electives. The proportion of engineering subjects provided in the Antioch curriculum is approximately twenty-five per cent, while the proportion in other colleges offering engineering courses averages approximately fifty-five per cent. It is therefore believed that the Antioch curriculum is such that it is better classed as a general scientific course with engineering as one of its elements rather than an engineering curriculum in the usual meaning of that term.

Carnegie Institute of Technology offers by agreement with the United States Bureau of Mines, the State Department of Mines of Pennsylvania, and the bituminous coal mining industry of the Pittsburgh district a post-scholastic training program of three years duration and confers the degree Engineer of Mines upon those successfully completing the program. The work is not, however, such as to be designated a ''cooperative engineering curriculum'' as previously defined.

Lafayette College offered a regularly organized cooperative course in mechanical engineering during the years 1922 to 1926 inclusive, but abandoned the plan in the latter year. The number of students who pursued this course was so small that it has been omitted from the tabulations. Further note regarding the trial of cooperative courses at Lafayette will be found on pages 678 and 679.

Worcester Polytechnic Institute offers an optional arrangement whereby students may take a course of non-resident engineering experience of fifteen months duration between the junior and senior years of the curriculum. Such students are placed with engineering organizations and follow a course of experience and training which has the approval of the Institute. The students are regularly in touch with their department of instruction at the Institute (Electrical, Mechanical, etc.) through letters and reports and through visits from members of the Institute staff. The Institute's official catalogue for 1926–27 lists four students of electrical engineering who are pursuing this option.

The Massachusetts Institute of Technology School of Chemical Engineering Practice.—In addition to institutions and curricula listed in Table I and to those mentioned in the paragraphs which follow the table, the curriculum offered by the Massachusetts Institute of Technology in its School of Chemical Engineering Practice should be discussed in connection with this report. The course is in a sense cooperative, but differs from the courses offered at the sixteen institutions listed to such an extent that it is not included with them. The plan has unique features and is one of the most interesting as well as one of the most valuable examples of the application of the cooperative idea. The cooperative part of the program is confined to the year immediately preceding graduation. The work of that year consists of one semester at the Institute devoted to advanced subjects in chemical engineering, and a period of twenty-four weeks devoted to plant study and testing at the various field stations of the school. The field work is essentially of a research nature. Little of it is repeated by successive groups of students Work at the plants is conducted under the direct supervision of members of the Institute faculty who devote their entire time to this work. While one group of students is at the Institute, the other spends one eight-week period at each of the three field stations. Studies are made of the chemical engineering operations involved in the manufacture of pulp and paper, sugar, heavy chemicals, steel, and other products. The work is done in connection with the regular industrial processes and on full-size apparatus and plant equipment. The student pays for his instruction while at the field stations and receives no pay from the industries. An important aspect of the plan is the benefit which accrues to the industries from the researches of the students. The course is open to graduate students of chemical engineering and leads to the degree Master of Science. Provision is also made whereby seniors of the undergraduate, four-year course may take the work at the field stations.

Location of Institutions.—Of the sixteen institutions offering cooperative courses, all but two are situated in cities of more than 100,000 population, and only one is in a strictly rural community. Twelve of the institutions are in the Middle Atlantic and Central States in which are concentrated most of the industrial activities of the country. Three of the institutions are in Southern States; only one institution is west of the Mississippi. Nearness to industrial activity has evidently been an important factor in instituting the cooperative plan.

Enrollment by Curricula.—The present (1925) distribution of student enrollment in cooperative engineering curricula is given in Table II.

TABLE II

ENROLLMENT OF COOPERATIVE ENGINEERING STUDENTS

	C.E.	E.E.	M.E.	Ch.E.	Others	Total
Cincinnati	248	336	195	123	242	1,144
Northeastern	267	389	198	142	36	1,032
Drexel	125	217	121	35	—	498
Pittsburgh	83	151	104	53	78	469
Marquette	109	166	78	29	65	447
Detroit Univ.	56	123	92	40	89	400
Georgia	48	—	—	—	282	330
M. I. T.		224*		50		274*
No. Carolina	87	93	8	—	—	188
Newark	—	91	42	39	3	175
Akron	55	55	36	—	—	146
N. Y. U.	9	19	40	7	36	111
Evansville		(Distribution not given)				95
So. Methodist		"	"	"		95
Detroit Inst.	—	63	19	5	1	88
Louisville	20	26	6	6	—	58
TOTALS	1,107	1,953	939	529	832	5,550

Courses are now given on the cooperative system in electrical engineering at 15 institutions; in mechanical engineering at 14 institutions; in civil engineering at 13 institutions; in chemical engineering at 11 institutions; in industrial engineering at 2 institutions; and in administrative, aeronautical, architectural, commercial, general, geological, and textile engineering, and also in "arts-engineering," at one institution each. Thus, with the exception of mining † and metallurgical engineering, all of the major engineering curricula are now offered on the cooperative plan.

Introduction of Cooperative Courses.—The years when the several institutions first offered cooperative courses are indicated in Fig. 1. The various features of this diagram are explained by the notes and key accompanying it. For the first twelve years of the history of the cooperative plan, its growth among the engineering colleges was relatively slow. Since the war period, however, the growth has been considerably accelerated, eleven institutions having adopted the plan between the years 1919 and 1925. It has been learned that two other institutions, in addition to those mentioned on page 563, are seriously considering the adoption of the plan in the immediate future.

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* Does not include some freshmen who have not designated their course of study.

† Beginning this summer (1926) cooperative work will be elective for freshman and sophomore students in the School of Mines at Pittsburgh.

● Indicates that the institution offered engineering courses prior to the introduction of cooperative courses.

☐ Indicates that the institution also offers all-resident engineering courses at present.

* Cooperative courses were abandoned at Lafayette in 1926; at Harvard in 1923.

Engineering curricula are indicated by numbers as follows:

Electrical	1
Mechanical	2
Civil	3
Chemical	4
Architectural	5
Industrial	6
Administrative	7
Aeronautical	8
Arts	9
Commercial	10
General	11
Geological	12
Textile	13
Mining	14

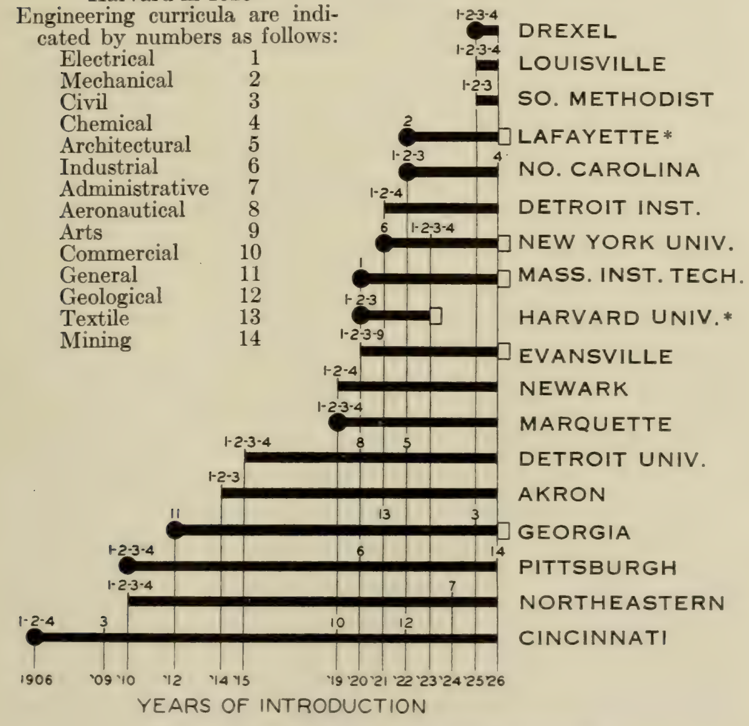

FIG. 1. Introduction of cooperative courses.

Abandonment of Cooperative Courses.—It will be observed from Fig. 1 that Harvard University adopted the cooperative plan in 1920 but discontinued it three years later, and that Lafayette College instituted a cooperative course in mechanical engineering in 1922 and discontinued it in 1926. In both cases the cooperative courses did not develop any considerable demand among the students and were abandoned primarily because of small enrollment. Since these two institutions are the only ones, so far as known, which have dropped cooperative courses after introducing them, the circumstances may be worth mentioning.

The plan at Harvard provided for three bi-monthly periods of industrial employment and four similar periods of classroom instruction between the end of the sophomore year and the beginning of the senior year, with no vacation longer than two weeks after the beginning of the junior year. It was limited to juniors in civil, electrical and mechanical engineering. Both cooperative and all-resident students had identical classroom instruction, which was given intensively; one-half the usual number of subjects being taken at one time at double rate. The plan proved unfavorable to cooperative students who were dependent upon themselves wholly or in large measure for their own support; it was unpopular with students living at a distance because of the short vacations; and failure in one subject usually meant delay in graduation or dropping of the industrial work. For all students, the effectiveness of instruction was diminished under the schedules adopted; and eventually separate courses were provided for the all-resident students. This resulted in triplicating the instruction in courses of the junior year. Thirty-four students elected the cooperative schedule during the first year after its adoption. In the following years the number adopting it diminished rapidly. Finally, the difficulty and expense of administering the same courses for the two groups of students seemed no longer warranted because of the small number of cooperative students and the plan was dropped in 1923.

The cooperative course in mechanical engineering at Lafayette was offered as an option to the all-resident four-year course. It was of five years duration. Cooperative training began at the end of the sophomore year and continued throughout the three remaining years, alternation between college and industry being at intervals of the college term. During the regular college year cooperative students took their places in the regular sections and during the summer special courses were provided for them at the college. The cooperative course did not prove popular with the Lafayette students. Not more than five students elected it in any one year, and the total number graduating during the years of its existence was seven. The last student graduated from the course in 1926 and it was then discontinued.

PART II. ORGANIZATION AND ADMINISTRATION OF COOPERATIVE COURSES

Purposes in Planning Cooperative Programs.—While the purpose common to all cooperative courses is to combine practical experience with scholastic training, there is considerable diversity in the plans which have been instituted in the several colleges for accomplishing this end. A study of cooperative programs shows a considerable range in the details of the work. There is also evidence of differences of purposes and ideals which tabulations of data do not entirely disclose. This has been aptly phrased by Timbie * as follows: "There is no standard cooperative plan of education. A cooperative program takes on the ideals, purposes, and standards of the school and companies cooperating." Modifications of the cooperative plan appear to be more than convenient expedients adopted to suit local conditions; they appear to be traceable to characteristic differences of attitude toward educational matters generally. This condition is not, of course, peculiar to cooperative courses, and is found in the methods employed in many types of educational programs. Attention is specifically called to it, however, since a tendency has been observed to regard cooperative courses as a standardized type of curriculum.

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* "Cooperative Course in Electrical Engineering of the Massachusetts Institute of Technology." *Journal of the American Institute of Electrical Engineers,* Vol. 44, No. 6, pp. 613–617.

While all of the plans for the application of the cooperative principle differ from each other more or less, they appear, in general, to fall into certain principal groups. In one instance the intent is evidently to make the cooperative work virtually an integral part of the curriculum; instruction of the student is continued while he is with the cooperating companies; and his program of experience is mapped out and administered so as to be auxiliary to and coordinate with instruction received in college. He pursues a definitely prescribed course of sequential training, all parts of which are selected with reference to their maximum educational value in the field of his particular curriculum. When the purpose of this type of cooperative program is attained, the periods of industrial experience become virtually an extension of the curriculum beyond the walls of the institution.

In another instance, while the student's industrial experience is in the field of engineering which he has selected, it is precisely the same as he would receive as a regular employee of the company, irrespective of his status as a cooperative student. The purpose here appears to be to place the student strictly on his own responsibility and to acquaint him with industrial requirements just as he would be required to meet them as a regular employee. This does not imply that the institution does not exercise general supervision over the student's industrial work or that it fails to advance him from one type of position to another, but that actual indusrial status and experience are the primary aim.

An example of a third type of program is afforded by that of the School of Chemical Engineering Practice of the Massachusetts Institute of Technology, to which reference has already been made. The intent here is evidently to utilize the facilities of chemical engineering industries for research and testing work on full-size equipment operating under regular industrial conditions. The laboratory work of a portion of the curriculum is thus transferred from the college, where full-scale work is impossible, to industrial establishments where such work can be done. Under this plan, the student remains at all times under the direct supervision of his college instructors, his class work is continued, and he is in no sense an employee of the cooperating companies.

Still another category into which cooperative training may fall may be termed "intermittent education." In such cases, the cooperative plan becomes merely part-time instruction and part-time employment with little relationship between the two.

These differences of purpose, as well as diversity in details of practice, should be borne in mind in examining the data regarding the organization and administration of cooperative programs as set forth in the paragraphs which follow.

Entrance Requirements.—Table III shows requirements for admission to cooperative courses. There is a considerable spread in the number of prescribed units, but not greater than is the case with all-resident courses.

TABLE III

Institution	Total No. of Units	Prescribed	Elective	Mathematics	English	Science	Foreign Language	History	Options	
									Restricted	General
M. I. T.	15	13 or 14	2 or 1	4	3	2	3 or 4	1	2 or 1	
Georgia	15	10½	4½	3½	3	1	2	1	4½	1
N. Y. U.	15	10½	4½	3½	3	1	3		4½	
Akron	15	10	5	3	3	1	2	1	2	3
No. Carolina	15	10	5	3	3	1	2	1		5
Pittsburgh	15	10	5	3	3	1	2	1		5
So. Methodist	15	9½	5½	3½	3	1		2		5½
Drexel	15	9	6	2	3	1	2	1	6	
Louisville	15	9	6	2	3	1	2	1	6	
Detroit Inst.	15	8	7	3	3	1		1	4	3
Detroit Univ.	15	8	7	3	3	1		1		7
Marquette	15	7½	7½	2½	3	1		1	3½	4
Newark	15	7½	7½	2½	3	2			7½	
Evansville	15	7	8	3	3	1		1	2	6
Cincinnati	15	6½	8½	2½	3			1	5½	3
Northeastern	15	6	9	2	3	1			9	

Graduation Requirements and Degrees.—The length of cooperative courses leading to the bachelor's degree is either four or five years, while the length of those leading to the engineer's degree is uniformly five years. The Massachusetts Institute of Technology confers the master's degree upon the completion of a five-year cooperative course, which provides a full quota of the Institute's requirements for the advanced degree, in addition to all of the regular undergraduate subjects of the electrical engineering curriculum, with the exception of some shop work. In the four-year courses, the period spent in school inclusive of examination periods varies from 84 to 137 weeks and the industrial periods total from 20 to 72 weeks. In the five-year courses the school period varies from 90 to 144 weeks and the industrial periods total from 65 to 139 weeks. These data are given in Table IV, and are also depicted graphically in Fig. 2. The usual requirement in institutions having full-time four-year courses is about 140 weeks. Two of the institutions on the cooperative plan confer the degree on the basis of less than two-thirds of this required period of school attendance.

The number of hours per week of classroom attendance required of cooperative students varies considerably in the different institutions, the range being from a minimum of 24 to a maximum of 35. These are actual hours, not credit hours. In total classroom hours required for graduation some of the five-year cooperative courses equal those of four-year all-resident curricula.* The total hours required in the various courses at Cincinnati, for example, equal those at Case School of Applied Science and Ohio State University, which were selected for comparison. In a number of cases, however, the difference in scholastic requirements of cooperative and all-resident courses is considerably greater than any allowance for time devoted to shop courses in the all-resident curricula.

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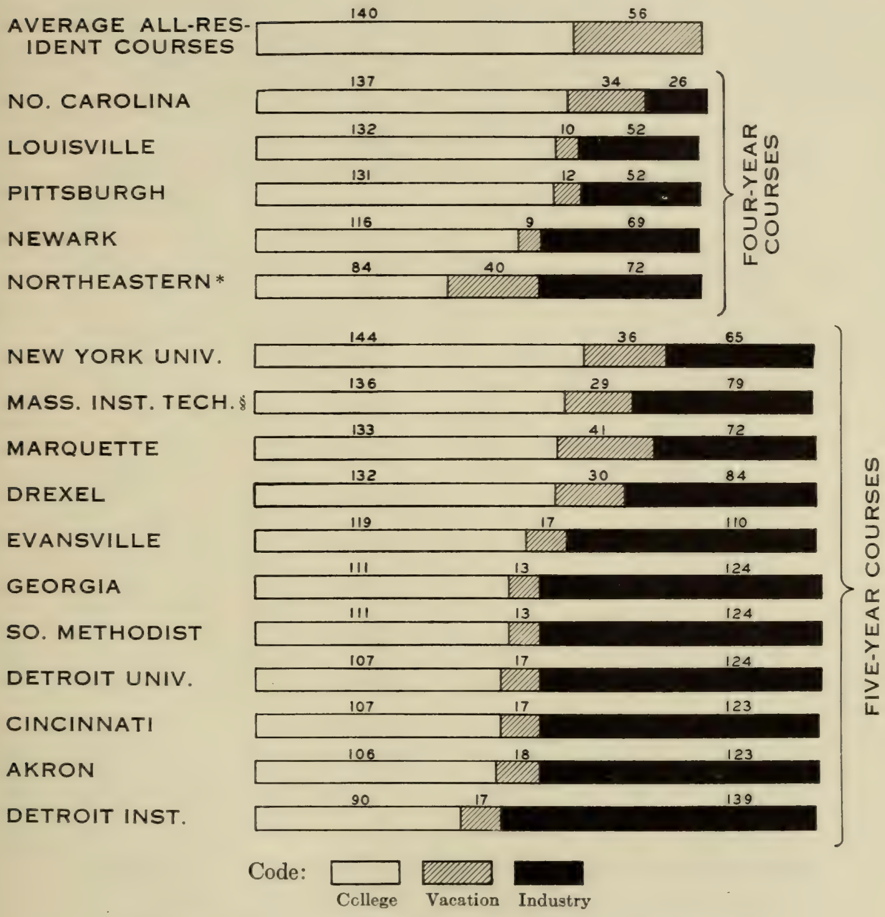
* The scholastic requirements of the five-year cooperative course in electrical engineering at the Massachusetts Institute of Technology exceed the Institute's requirements in all-resident four-year courses. Some of the subjects of the curriculum are taught by members of the regular teaching staff of the Institute to classes of students while they are at the plants of the cooperating companies.



* Students may take either 20 or 72 weeks of industrial work.
§ See footnote (‡), Table IV, page 574.

FIG. 2. Distribution of time in cooperative courses.

TABLE IV

LENGTH OF COOPERATIVE COURSES

Degree	Length of course in years	Total weeks required in	
		School	Industry
Bachelor of Science			
Detroit Inst.	5	90	139
Drexel	5	132	84
Georgia	5	111	124
Louisville	4	132	52
Newark	4	116	69
No. Carolina	4	137	26
Pittsburgh	4	131	52
So. Methodist	5	111	124
Bachelor of Electrical Engineering, etc.			
Detroit Univ.*	5	107	124
Marquette †	5	133	72
Northeastern			
1 cooperative yr.	4	124	20
3 cooperative yrs.	4	84	72
Civil Engineer, etc.			
Akron	5	106	123
Cincinnati	5	107	123
Evansville	5	119	110
N. Y. U.	5	144	65
Master of Science (in E.E. together with B.S. as of previous year)			
M. I. T.	5	136‡	79

Periods of Alternation.—No other single feature of cooperative courses has been given more extended study than the

* The University of Detroit awards the degree of B.S. in the several branches of engineering to those who complete the course of studies in school but who have not completed the industrial work.

† Classes which entered prior to October, 1925, pursued curricula leading to the degrees C.E., Ch.E., E.E. and M.E.

‡ While this figure includes all of the time actually spent by the student at the Institute, it does not include the time devoted to regular subjects of the curriculum which are pursued while the student is at the plants of the cooperating companies. This is equivalent to fifteen weeks of resident study at the Institute. The total time devoted to scholastic instruction would be increased from 136 to 151 weeks if this time were added.

periods of alternation between institutions and industry. That the problem has not been solved with complete satisfaction appears certain from the diversity of present practices.

The periods of alternation between college and outside work vary from two weeks to the semester of approximately four months. This plan of alternation extends from a single year to the full four or five years of the curriculum. Table V lists the institutions arranged according to the period of alternation. These periods at some colleges are not rigidly adhered to during part of the year, usually the summer term. Northeastern starts with a 20-week period and changes to five weeks at the beginning of the sophomore year. Newark offers both two-week and four-week alternation plans.

TABLE V

PERIODS OF ALTERNATION BETWEEN COLLEGE AND INDUSTRY

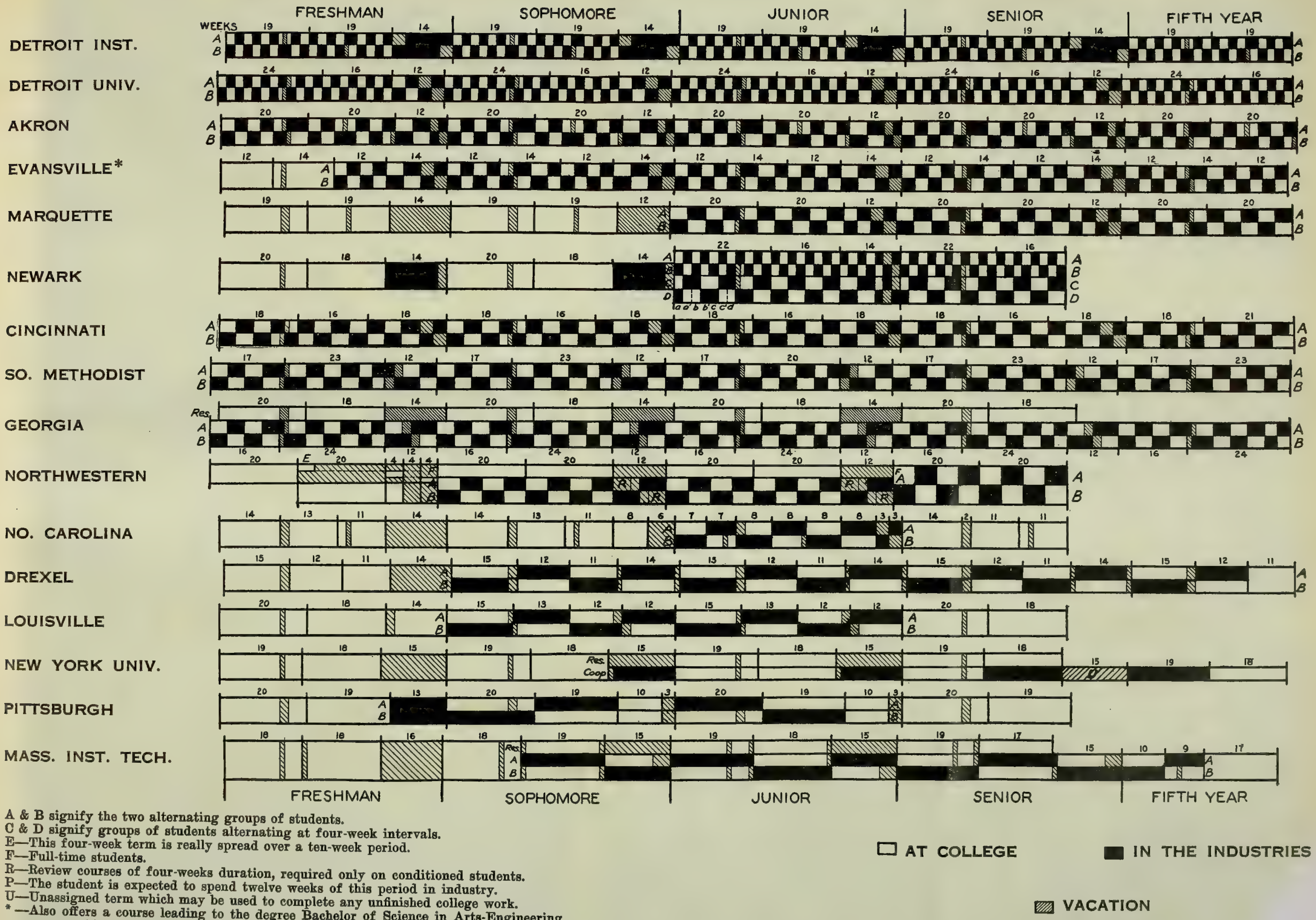
Period.	Institution.
2 weeks	Detroit Inst., Detroit Univ., Newark
3 weeks	Akron, Evansville
4 weeks	Cincinnati, Georgia, Marquette, Newark, Southern Methodist
5 weeks	Northeastern
8 weeks	North Carolina
3 months	Drexel, Louisville
Semester	M. I. T., N. Y. U., Pittsburgh

In general, periods of alternation appear to fall into one of two classes, the short period, and the long period. Administrators of cooperative courses point out that there is a choice between two principles in this connection. Some state that the short period is selected with a view to minimizing the effects of discontinuity of instruction, and maintain that with a period of four weeks or less the student is able to take up his class work upon returning from industry at the point where he left off at the end of the previous college period without serious "lost motion." The longer period of a term or semester, on the other hand, is selected because subjects of instruction or major divisions thereof can be completed during a single period at the college and because the student is thus enabled more fully to participate in undergraduate activities. There appears to be a division of opinion as to which of these plans is the more advantageous. The tendency, in general, seems to be in the direction of longer periods of alternation. In institutions which offer all-resident as well as cooperative courses in engineering, the selection of the term or semester as the period of alternation offers obvious advantages in simplification of schedules and avoidance of duplication of instruction.

In at least one institution, the Massachusetts Institute of Technology, which employs the semester as the period of alternation, the instruction of the student is continued while he is at the plants of the cooperating companies. Members of the Institute faculty conduct classes at the plants in regular subjects of the curriculum. Continuity of instruction is thus maintained throughout the entire course.

Period at which Industrial Experience Begins.—The period of the curriculum at which industrial experience is first introduced also varies widely. At several of the institutions the student spends all of his time in college for one, two, or even three years before the periods of alternation with industry begin. Some express the belief that the freshman is none too young to begin his experience in the ''school of hard knocks.'' Others believe that a period of orientation to college life of one or more years is highly desirable from the viewpoint of both student and institution. It is felt that such an initial period also serves to relieve the employers of a large turn-over of personnel. Practices in this matter are shown graphically by Fig. 3.

Cooperative Schedules.—The cooperative schedules for the full course at the sixteen colleges are shown in detail in Fig. 3. Each diagram depicts the commencement and termination of the interval of industrial affiliation and also the periods of alternation between college and industry. While these schedules have been made with care in accordance with all the information at hand, there may be some minor inaccuracies in allowing for vacations and examinations.



A & B signify the two alternating groups of students.
C & D signify groups of students alternating at four-week intervals.
E—This four-week term is really spread over a ten-week period.
F—Full-time students.
R—Review courses of four-weeks duration, required only on conditioned students.
P—The student is expected to spend twelve weeks of this period in industry.
U—Unassigned term which may be used to complete any unfinished college work.
* —Also offers a course leading to the degree Bachelor of Science in Arts-Engineering which may be taken on all-resident or cooperative plan.
Res.—Resident students.

FIG. 3. Alternation periods in cooperative schedules.

Some features of the diagram and of the operating details of cooperative programs are explained in the following notes:

In the schedules for Georgia, M. I. T., and N. Y. U. in Fig. 3, the upper portion shows the school periods for the four-year all-resident courses for purposes of comparison. At Evansville, students having two years' credit in liberal arts subjects may transfer to the arts-engineering course requiring either four years' full time, or 6 quarters full time plus 10 quarters of cooperative or ''half-time,'' for the degree of B.S. in Arts-Engineering. Students at Cincinnati pursuing the course in geological engineering alternate at about six-month intervals beginning with the fourth year to enable them to take part in topographic surveys where work must be continuous and may be in remote locations.

Letters *A* and *B* in the chart designate the two groups into which the student body is divided so that one group may alternate with the other to maintain continuous industrial employment. The letters *C* and *D* are used similarly in the Newark schedule to denote the groups which alternate at four-week intervals to distinguish them from the groups *A* and *B* which alternate at two-week intervals. The schedule of this college shows how two periods of alternation, one twice as long as the other, may be used at a college concurrently by different students without further duplication of instruction. The small letters *a, a′, b, b′, c, c′,* etc., at the beginning of the junior schedule denote definite portions of each subject taught during the school term, portions *a* and *a′* being alike, *b* and *b′* alike, etc. Thus in successive school periods group *A* receives instruction *a, b, c,* . . . group *B* receives *a′, b′, c′,* . . . group *C* receives *a, b′, c,* . . . and group *D* receives *a′, b, c′,* . . . . A few students at Evansville, where the normal shift is made every three weeks, have been placed on a six-week basis. The double period plan also is being considered for adoption elsewhere.

Continuity of industrial service by a student and his alternate is an essential feature in the cooperative schedule for the short periods of alternation. With the semester periods of alternation used at N. Y. U. the system of alternates is not important, and in fact the students are not divided into the two groups *A* and *B* as elsewhere. However, if an employer desires a pair of students for continuous work, a junior would be selected as an alternate for a senior and the alternation would be effected as indicated by the wavy line in Fig. 4, which shows the schedules of the five classes that entered in successive years. The unshaded areas represent four-month periods at school and the black areas equal periods in industry, without reference to vacations. The industrial term following the sophomore year does not play a part in maintaining continuity of industrial service and causes twice as many students to be employed during the summer as during the other terms.

The schedule of N. Y. U. illustrated in Fig. 4 for both the all-resident and cooperative engineering courses presents a unique feature in that no instruction whatever is duplicated and no regular instruction is given during the summer. The school terms are numbered from 1 to 8 and the four industrial periods are numbered from I to IV. For the cooperative student there is a gap of exactly one year between the seventh and eighth terms in college, two-thirds of which period is devoted to industrial work and the remainder is unassigned. The unassigned term, marked U, may be used by the senior for completing unfinished school work, or for taking courses in the Summer School of the University, or for additional industrial experience. If the student is not paired with a junior, he may interchange terms III and U in order to repeat second semester subjects, or interchange terms IV and U to repeat first semester subjects. Transition from all-resident courses to cooperative on the foregoing plan could be made by an institution with little inconvenience and without involving a change in its teaching schedule.

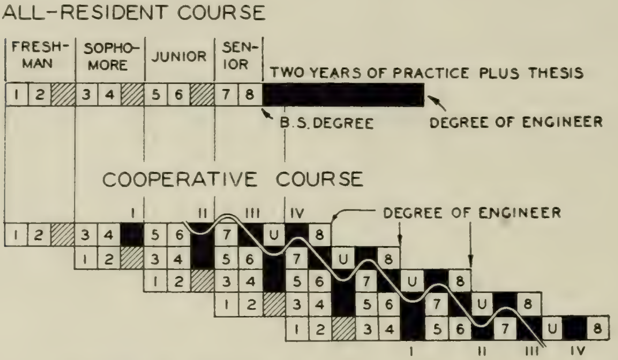


FIG. 4. All-resident and cooperative schedules at New York University.

Coordination.—The method by which the coordination between college work and industrial experience is accomplished is one of the important features of the cooperative plan. In most cases direction of the student's industrial employment is in charge of one or more individuals, known as coordinators, directors of industrial cooperation, and the like. In several institutions, such as Cincinnati, for example, there is a complete staff of coordinators which reports to the dean and acts independently of the teaching faculty. In others, certain members of the regular teaching staff devote part of their time to supervision of the students' industrial work. One institution reports that it has no coordinator and no activity corresponding to the coordinating function. The number of students per coordinator varies from 25 to 170.

Coordinators are usually given faculty rank, ranging from Instructor to Associate Professor. In some instances coordinators are not given faculty rank but are designated Director of Industrial Cooperation and the like. Practically all of the coordinators are engineering graduates; most of them have had industrial experience; a goodly proportion are Cincinnati graduates.

The work of the coordinator includes the following:

(*a*) Establishing relations with firms and arranging for positions.
(*b*) Keeping these positions filled.
(*c*) Shifting students about so that their training shall be progressive.
(*d*) Keeping records of the students' progress.
(*e*) Maintaining sufficiently close contacts with students and firms so that troubles can be adjusted or foreseen and prevented.
(*f*) Acting as advisers to the students and assisting them to get the most out of their industrial experience.

There is considerable range in the matter of the closeness of the supervision of the student's industrial work. In most cases the coordinator visits the various cooperating firms at intervals and interviews both the student and his superior. In many cases the student is required to submit written reports during or upon completion of each period in industry. In some cases reports are submitted as often as once a week; in others, once each working period, even though it be twelve weeks long. Weekly or bi-weekly reports are often mentioned. Reports are submitted to the coordinator or to the head of the student's department in college, and in some cases are also criticized by members of the Department of English.

Contact of students and coordinators is effected in one or more of several ways, of which the following are illustrations:

(*a*) Personal interviews with individual students during both school and industrial periods.
(*b*) Meetings of the coordinator with entire classes or sections. Such meetings are scheduled as is any classroom exercise and are often called "Class in Coordination."

Where frequent individual personal contacts are possible, the intent seems to be to maintain an approximation to the idea of laboratory instruction; where the contacts are less frequent or less personal, the intent apparently is to initiate the student into the state of mind of the worker and to put him completely on his own responsibility. On the other hand, it costs less to conduct the work of coordination by classes than it does by individuals.

How Closely are College Work and Industrial Experience Coordinated?—A question frequently asked regarding cooperative courses is—"To what extent is it possible to correlate the student's industrial experience with his college studies?" Statements received from the institutions indicate that there is no great difficulty in obtaining broad correlation with the student's major field of study, *i.e.,* employment may readily be arranged along the general lines of the several curricula.

There is, however, little or no attempt at what some term "day by day coordination" between the industrial work of a given period and the subjects studied in the preceding school period. A number of institutions state that this often occurs accidentally. In several institutions opportunities to bring about this type of coordination (as, for example, work in a field party with simultaneous classroom study of surveying) are utilized as they occur, but no attempt is made to provide it in all cases or throughout the curriculum. In fact, the variety of studies pursued by engineering students would make this impossible.

Endeavor to provide for correlation of college and industrial work is also reflected in some cases in the arrangement of the curriculum itself, as, for example, the placing of elementary surveying in the freshman year for civil engineers, elementary electrical engineering in the freshman year for electrical engineers, and the like.

Rating of Industrial Work.—The work of the student in industry is usually rated or evaluated according to some particular system. In some institutions this rating is dispensed with, on the assumption, apparently, that the employer's permission to remain on the work is sufficient evidence of merit.

The majority of schools, however, use one or more of the following methods:

(*a*) Conferences by the coordinator with the employer or his representative, preferably with the student's immediate superior. The advantage of this system is that a student is rated by a single experienced individual upon the basis of evidence and opinion gathered by him.
(*b*) Reports by employers' foremen on forms supplied by the school, made up in such a way that check marks in various spaces designate the student's rating. If thoughtfully and carefully made, these ratings are excellent, but there is evidence that they are often done perfunctorily. Owing to the fact that there are often as many foremen supplying ratings as there are students to be rated, the results are likely to be very diverse.
(*c*) Reports submitted by the students themselves to the coordinator. If these reports are carefully rated, they doubtless furnish a good indication of the student's work and progress.
(*d*) Examinations on return to college. Apparently, only one school uses this method.

The forms used in methods (*a*) and (*b*) designate a number of personal qualities and points which tend to evidence the grade of the student's work; such, for example, as reliability, initiative, self-reliance, application, interest, speed, and the like. Opposite each of these are placed spaces for a five-point or a three-point rating scale with descriptive adjectives ranging from high merit to failure.

These ratings form a part of the records relating to each student. They are filed for reference as are ordinary scholastic or personnel records, and they also serve to aid in properly placing the student after graduation.

Earnings of Cooperative Students.—Whether the matter of earnings by the student during his course is or is not looked upon as a matter of major importance, it is certainly worthy of consideration. Studies made by other committees of the Society indicate that engineering students, generally speaking, come from homes of modest means and that considerable numbers of them earn all or a substantial part of their college expenses through employment during vacations and term time. The cooperative plan offers a means toward the solution of the financial problem of many students.

It is to be noted that the colleges endeavor to prevent undue emphasis upon this matter by stating that earnings from industrial work are entirely subordinate to the educational aspects of the cooperative plan.

During the early part of the curriculum, rates of pay are seldom more than sufficient to meet the student's living expenses while he is working in the industries. Toward the end of his course, however, he is earning at higher rates and can no doubt lay aside some money toward payment of his college expenses. Figures on earnings supplied by the colleges give ranges between the following limits (earnings are given in dollars per week):

	1st Year	2d Year	3d Year	4th Year	5th Year
Lowest	15.50	20.00	22.00	25.00	25.00
Highest	24.00	30.00	34.00	40.00	50.00

If it is desired to compute the student's total earnings for a year, it must be remembered that he works but half the year; if earnings for the entire school period are to be computed, it must be remembered that cooperative training does not always extend over the full course.

The lowest figures are from a Southern institution, the highest are from an institution in a locality where wages are generally considered high. To give a fair comparison, living costs should be included.

Relations between Colleges and Industrial Firms.—Affiliations with industrial firms appear to be quite generally based upon the following ideas:

1. Firms of good repute should be selected and preference

given to firms which are large enough to afford a sufficient variety of experience, and centralized enough to have a unity of policy.

2. Preference should be given to plants situated near the college, especially if alternation periods are short.

3. In seeking affiliation with a concern, the highest possible officers should be interested in the plan and they should be led to endorse it heartily as a method of training men for their organization.

4. Firms should be willing to cooperate in giving students opportunities to obtain well-rounded experience under actual working conditions.

5. The organization of the firms should be such that cooperative students are easily accessible to the coordinator for interviewing.

6. Each firm should have some officer to act as representative for its students, as well as to look after the interests of the firm.

7. While the character of experience gained by the students is more important than the salary received, it should not be forgotten that the latter may be a determining factor with some students.

For the most part the cooperating industries do not maintain specific organizations for the purpose of training cooperative students, though there are important exceptions. Several large corporations having educational departments or maintaining cadet systems, apprentice systems, etc., employ the organizations devoted to such matters to deal with the cooperative students at their plants. In the smaller firms entire reliance seems to be placed on the coordinator to look after his students, to see that they are shifted sufficiently to get new experience, to obtain raises of pay for them, and so forth.

Selection of Students for Cooperative Work.—The selection of students for work in the various concerns is usually made by both the college and the firm. The coordinator usually takes the initiative and recommends students to the cooperating concerns. Often this is all that is necessary to secure employment up to the limit of numbers agreed upon by the firm, although some firms make a selection from the candidates so recommended. Not all of the students at M. I. T. who desire to take the cooperative course in electrical engineering are selected by its five affiliated industries because they limit the number of men taken on to sixty-six per year. Through verbal agreements with the Institute, these concerns virtually guarantee employment for three years to the following numbers of students from each class: General Electric Company, thirty; Bell System, twenty; Stone & Webster, ten; Boston Edison Company, four; and Boston Elevated Railway, two. These men are expected to stay with the one firm for the entire course; in fact, many retain employment with their companies after graduation. Forty-six per cent of the M. I. T. cooperative graduates are still with the cooperating companies.

The majority of institutions report that it is preferable for a student to take all of his industrial work with one concern, provided this firm has sufficiently varied work to give him a wide range of experience. If cooperation is undertaken with the smaller firms because of the value of certain lines of experience which they offer, it is definitely understood that the students will remain for limited periods only. Some firms require a contract (after a short trial period) for a definite time, one and two year periods being mentioned. One school reports that it will not permit any such contracts.

Where changes from firm to firm are made, such changes nearly always require the permission of the coordinator, and often of the dean and department head in addition. In one institution the consent of the firm and the real reason for leaving are required from the student, presumably in addition to the above. Changes would naturally take place at the regular period of alternation, but a student might be required to serve out a period of notice to the firm.

Status of the Student in Industry.—While engaged in industrial work, students are placed on the same footing as the regular employees. So far as can be learned, there has been no general opposition to the employment of engineering students on the part of organized labor. Where strikes have occurred the students have been withdrawn and placed with other companies.

Care obviously must be exercised by the colleges in selecting their students so that no serious difficulty will be experienced in finding positions for them because of racial or physical limitations. Several colleges state that all students likely to meet with such difficulties are advised before entering the cooperative courses as to the preferences of industries, but that no restrictions are made by the school.

Since industrial depressions may interfere with cooperative work in industry, it may be well to mention that at one institution a committee makes periodic surveys of the economic conditions of the affiliated concerns, and students are withdrawn in anticipation of an industrial retrenchment and are placed elsewhere.

Elimination of College Shops.—The elimination of woodworking and machine shops, and of the courses in shopwork, is often mentioned as one of the benefits accruing to the college when operating on the cooperative plan. Eleven of the schools report to this effect, but a few make reservations. One omits woodshop equipment and the subject of woodwork, giving instruction in other shop courses; another omits no shop courses. Three institutions made no reply to this question.

Four institutions omit ''considerable surveying,'' one ''considerable drafting,'' and one ''specialized machine design.'' Two institutions state that most laboratory equipment can be reduced in amount, though they list no reduction in laboratory subjects.

Numbers of Students and Teachers.—Obviously, with a given physical plant a greater number of students can be accommodated under the cooperative plan, but reflection will show that the number of students per teacher cannot be increased without increasing the load of teaching per member of the staff. In the majority of cases, particularly when the period of alternation is other than the academic term or semester, the engineering teaching staff is on duty throughout the year, except for one or more vacations, these usually being one or two weeks at Christmas, and a summer vacation varying from a ''catch as catch can'' period of two weeks to a more generous one of four to five weeks; these are naturally made to correspond with the vacations of the students. With the short period of alternation, where it is usually considered essential to keep the industrial positions always filled, vacations have to be taken at different times by different persons. With the longer periods, especially where they correspond to the semester, it is possible to maintain the customary collegiate vacations—Christmas, spring, and summer.

Costs.—Little information is at hand in regard to the cost of instruction at cooperative schools. Studies previously made by other investigators show such a wide variation in the cost per student per year at many all-resident institutions that unqualified comparisons are misleading. Nevertheless, a comparison in costs between the Case School of Applied Science and the University of Cincinnati will be of interest, since both are in the same general locality, both have complete teaching staffs under the direction of the Dean of Engineering, and both have nearly the same salary scale. At Case, with 580 students and 57 instructors, the cost per student was $560 per year in 1923–24 (including all budget items, but excluding interest and depreciation), while at Cincinnati, with 1,136 students and 53 instructors, the cost on the same basis was $340 per student in 1924–25.

PART III. APPRAISAL OF VALUE OF THE COOPERATIVE METHOD

The really fundamental question for consideration in this report relates to the soundness and value of the cooperative plan and its advantages both on an absolute basis and in comparison with the older ''regular'' engineering curriculum. It would be extremely desirable in this report to formulate a definite answer to this question, or at least to determine definitely the peculiar merits of the cooperative plan and its particular and proper place in the general scheme of engineering education. It must be stated at the outset that no definite conclusion warranting a concrete, unequivocal statement has been reached. It is probably inevitable that such should have been the outcome. Fundamental problems of education are so complex and the results of educational processes so intangible that it is often impossible to reduce them to the basis of concrete analysis and objective valuation.

Probably the best approach to a judgment as to the value of cooperative engineering training is to cite such facts as are available; to set down the opinions, pro and con, in the matter; impartially to discuss both facts and opinions; and to leave the reader free to draw his own conclusions. If experience in such matters is any guide, in many cases he will then proceed to do this in accordance with his preconceived opinions or convictions arrived at by reason of his training, associations, or general viewpoint on educational matters.

A. Analysis of Available Facts

Nature and Source of the Data.—As intimated above, the element of objectivity would be very valuable in connection with such a study as the present. It is extremely difficult, however, to gather a body of data which is both sufficiently comprehensive and sufficiently accurate to furnish a basis of judgment. It would be even more difficult to conduct any ''controlled'' experiment or test which would be of real value. In considering this problem it was concluded that possibly some evidence of value might be extracted from information regarding the careers, advancement, earnings and other matters relating to graduates obtained in connection with another study.* Accordingly, data supplied by graduates of two institutions, one offering cooperative and the other all-resident curricula, were analyzed and compared. These two institutions, while differing in the types of programs offered, are alike as to environment, number of students enrolled (if the number of cooperative students attending classes at one time be taken as the basis of comparison), size and general quality of faculty, and quantitative scholastic requirements for graduation. Both are institutions of excellent standing. One institution exercises complete control over its admission requirements. The other is obliged to admit all graduates of the high schools of its city, from which source approximately four-tenths of its entering students are drawn. Tests of training and aptitude * given to freshmen of the two institutions indicated no marked differences in the ability and preparation of the student bodies. Apparently both institutions attract students of good ability at present. It was not possible, however, to form any judgment as to this matter in the past. These two colleges will be designated ''A'' and ''B'' in the tabulations which follow.

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* See Bulletin No. 3 of this series—''A Study of Engineering Graduates and Former Students, Non-Graduates.''

It was hoped that the results of this analysis might serve to measure the results of the two types of programs. It will be observed from the condensed summary of results which follows that the findings are largely inconclusive. They show no marked differences between the two groups of graduates. This may, of course, be due to limitations of the method employed, or to other factors.

Among other points covered by the comparison are: The number of positions occupied by graduates in a given period after graduation; the relationship of fields of work of graduates to courses pursued in college; types of positions occupied —administrative, supervisory, technical, and so forth; and earnings and rates of advancement therein. The reactions and opinions of the graduates on questions relating to the quality of their instruction in college, satisfaction or dissatisfaction with their present positions and prospects, studying done since graduation, and other matters, were also studied.

Number of Positions Occupied.—Graduates of the all-resident courses showed fewer changes of position in the first two or three years after leaving college than did the graduates of cooperative courses. This was striking among graduates of the class of 1922. The tabulation which follows shows the percentages of the class holding one, two, or three distinctly different positions during the first thirty months after graduation.

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* The Iowa Placement Examinations were given to freshman classes in the two institutions in the fall of 1925.

	Cooperative Graduates Institution A	All-resident Graduates Institution B
One position	26.6%	50.0%
Two positions	46.7	25.8
Three positions	26.7	24.2

Among members of the class of 1923, cooperative graduates showed slightly greater stability during the first eighteen months after leaving college. The reverse was true of graduates of the class of 1924.

Relationship of Fields of Work to College Courses.—In making this analysis, the fields of work of graduates were classified in four divisions: (1) the *same* field as that of the student's course in college, (2) a *closely associated* field, (3) *''other''* engineering fields; *i.e.*, those not closely related to courses pursued in college, and (4) *non-engineering* fields. The composite results for graduates of all courses of the two institutions show almost identical proportions in these four divisions, the figures being as follows:

	Cooperative Graduates Institution A	All-resident Graduates Institution B
Same field	52.9%	48.0%
Closely associated field	10.1	10.6
''Other'' engineering	24.0	25.4
Non-engineering	13.0	16.0

A more detailed analysis shows, however, that a considerably larger proportion of cooperative graduates of electrical and mechanical engineering remains within the same field as their college course than is the case with all-resident graduates. The reverse is true of chemical and civil engineering graduates. These differences were especially apparent among the younger graduates. There may be some significance in these results. It is possible that they indicate greater adaptability of the cooperative graduate to the field of operating and administrative duties connected with manufacturing industries which is entered by electrical and mechanical engineering graduates to a very considerable extent.* The evidence quoted is probably not sufficient in itself to warrant such a general conclusion, though it appears to point in that direction.

Types of Positions Occupied.—The division of occupations of graduates among the several functional, as distinguished from the technical, types of activity is shown below.

Types of Positions	Cooperative Graduates Institution A		All-resident Graduates Institution B	
	Recent Classes	Older Classes	Recent Classes	Older Classes
Primarily administrative—owner, proprietor, executive, administrative, supervisory, etc. . . .	27.7%	58.1%	24.3%	60.0%
Primarily technical—design, estimating, drafting, testing, operation and maintenance, etc.	55.9	19.6	60.6	24.6
Research and teaching	11.5	16.1	12.5	13.4
Miscellaneous	4.9	6.3	2.6	2.0

The figures for the two institutions exhibit a striking similarity.

Earnings.—Statistics on the earnings of the graduates of the two institutions are interesting. The following table gives the median † earnings, as of approximately January 1, 1925, of graduates having the numbers of years of experience indicated. The proportions of graduates reporting were from 35 to 40 per cent and were practically the same for the two institutions. The table affords not only a comparison of earnings of graduates of the two institutions, but also a comparison with the earnings of a large group of graduates of a number of institutions throughout the country.

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* For statistical evidence on this point see Bulletin No. 8 of this series —"A Study of a Group of Electrical Engineering Graduates," pages 370 and 371.

† The median is the middle number and has as many numbers larger than itself as it has numbers smaller than itself.

	Cooperative Graduates Institution A	All-resident Graduates Institution B	Graduates of many Institutions *
Immediately after graduation	$1,740	$1,500	$1,476
One year after graduation	2,060	1,800	1,800
Two years after graduation	2,400	1,990	2,100
Three years after graduation	2,720	2,142	2,400
Five years after graduation	3,120	3,000	2,860
Ten years after graduation	4,275	4,350	4,000

The following tabulations show the progressive advancement in median earnings of members of two particular classes.

	Years After Graduation						Number Reporting
	0	1	2	3	5	10	
Class of 1919							
Cooperative	$1,750	2,000	2,400	2,600	3,000		24
All-resident	$1,200	1,740	2,000	2,142	3,000		24
Class of 1914							
Cooperative	$ 900	1,150	1,465	1,860	2,660	4,240	24†
All-resident	$ 780	936	1,200	1,800	2,400	4,350	29

It must be remembered in comparing the earnings of graduates of these institutions that the cooperative course is one year longer than the all-resident course, five years instead of four, and consequently that the cooperative graduate is one year older than the all-resident graduate of the same number of years of experience. Furthermore the cooperative student has received industrial training during his undergraduate years of as great duration as, or of greater duration than, that received by the all-resident graduate in his first year after graduation. In fairness, therefore, figures for the same number of years of experience should not be compared. If graduates are to be considered on the basis of equal ages and approximately equal experience, earnings of the graduates of the cooperative course immediately after leaving college should be compared with those of all-resident graduates one year after graduation, those of cooperative graduates of one year's experience with those of all-resident graduates of two years' experience, and so forth. If this is done, it will be

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* These figures are taken from Bulletin No. 3 of this series, pages 233, 260 and 261.

† Classes of 1913, 1914 and 1915 were included in order to obtain a larger number of cases. Figures for the three classes are quite similar.

observed that the two groups earned almost identical amounts in their early years. The inclined lines in the tabulations indicate the figures which should be compared on this basis.

It should be clearly understood that these figures and the discussion of them are based upon a limited number of cases and are therefore uncertain. The percentages of individuals who responded to the request for information are very nearly the same in the two cases, and the institutions probably afford as valid a comparison as any which could be selected. The data supplied by the larger group of graduates of many institutions also serve as a check. Nevertheless, the results ought to be taken merely as tentative.

Replies of Graduates to Other Questions.—In their replies to questions as to the quality of instruction received in college, its relationship to practical needs after graduation, attitude toward positions and prospects, liking for engineering as a vocation, and other similar questions, the graduates of the two institutions indicated little or no difference of view. Both groups appear to think highly of their college courses and the preparation afforded them for careers in engineering.

Limitations of Statistical Evidence.—It is perfectly clear, of course, that the evaluation of cooperative courses can not rest entirely on evidence which can be expressed in statistical form. One of the best indices of the value of an educational program is the degree of responsibility pertaining to positions occupied by its graduates. It is practically impossible, however, to reduce such information to valid statistical statement. It is also evident in the present instance that the period which has elapsed since the establishment of cooperative courses has been so short that the data relating to graduates are inclusive. Relatively few graduates of cooperative courses have had as much as ten years of experience at the present time. Probably at least twenty years and possibly more will be needed to indicate the position which the cooperative graduate will achieve in the field of engineering.

B. Analysis of Opinions Relative to Cooperative Training

Source of the Opinions.—A second aid to the effort to appraise the cooperative system, which naturally suggests itself, is an analysis of the opinions of those competent to express themselves. In the present study, opinions were sought only from those whose experience, position, and opportunity for observation were such as to qualify them to express themselves. At the same time the effort was made to select individuals representing different points of view in the matter. Questionnaires were sent by the committee, to administrators, teachers, and coordinators in institutions offering cooperative courses, and to men in industry who have had experience with cooperative students and graduates. Many of these individuals are themselves graduates of cooperative courses. As a whole, the group is made up largely of advocates of the cooperative plan, who might be expected to give *ex-parte* opinions. It proved to be difficult to obtain the views of those likely to hold a more impartial viewpoint as completely or systematically as was needed to give a balanced summary. As is usual in controversial matters, those who are strong advocates of a plan or proposal have usually formulated their arguments and opinions more concretely than those having a less direct and vital interest in it. Nevertheless, a considerable body of opinion, both pro and con, has been gathered by means of the questionnaires. This has been supplemented by views expressed in conferences and by statements appearing in print.

The summary which follows is an attempt to arrange these opinions in orderly fashion. Opposite each argument advanced either for or against the cooperative system a counter argument or rebuttal has been set down. These arguments were gleaned from the results of the canvass mentioned above and are not the views of the committee or the Staff.

Advantages to the Student—Educational and Vocational

For the Plan (*Statements of Advocates*)	*Against the Plan* (*Statements of Opponents*)
The cooperative plan provides systematically coordinated instruction in principles, and practical training in their application. The relationship of theory to practice is shown. The student is trained in the use of knowledge. Respect for and interest in the principle is thereby increased and the learning process is accelerated. Many details and methods of practice which cannot be taught adequately in the classroom are learned through observation in industry.	These claims are based largely upon an assumed correlation of college and industrial work which is more of an ideal than an actuality. The types of positions occupied by cooperative students, particularly in their early years, when much of the basic theory of science and engineering is taught, are not such as to make possible any demonstration of the application of principles learned in college.
Periods of practical industrial experience develop the student's personality and strengthen his character. His courage, resourcefulness and stamina are tested; his sense of responsibility is brought into play; self-confidence and initiative are developed. Industrial experience acts as a much needed steadying influence. The student learns to see things in their true light and to value them accordingly; in particular he is more likely to appreciate the value of his education.	The inference is that the ordinary college course does not accomplish these ends as well. This is not proved and probably cannot be demonstrated objectively. It must be remembered that the great majority of engineering students work during their vacations and are thus tested in the manner indicated. There may be some basis, however, for the claim that the cooperative course provides a much better opportunity, under systematic guidance, for the development of traits of character not brought into play in the college environment. If so, it constitutes one of the greatest advantages of the cooperative system.
Practical work is the best form of educational and vocational guidance. The student acquires a knowledge of one or more lines of work through first hand experience. He is thus able to choose his field	Answers to these claims fall into two classes. One group concedes that the cooperative plan appears to possess merits in providing a means of valid vocational guidance. They point out, however,

of work and a particular position in it with some discrimination. Transition from college to practical life is prepared for and is easily made upon graduation.	that colleges offering all-resident courses are recognizing the need of practical guidance of students and are providing for it through orientation courses, lectures and other means. The other group is inclined to believe that the colleges have already gone too far in a paternalistic attitude and that both students and graduates should be thrown very much more on their own resources, particularly in choosing fields of work and in obtaining employment. They are inclined to believe that the cooperative plan accentuates ''coddling,'' which they deplore.
Through intimate contacts in industry the student obtains an insight into labor problems and a knowledge of the reactions and psychology of the working man. He thus learns to appreciate and respect the problems of the men he will subsequently direct. The best time for the young man to acquire the proper point of view in these matters is while he is still young. The graduate is not likely to have either the opportunity or much inclination to do so.	It is generally admitted that this is probably a valuable feature of the coöperative plan.
The student learns to get along with others, to work under supervision, to follow instructions and to abide by the decisions of his superiors. Thus, from the discipline of obeying instructions, he learns to direct the work of others. In general, he is brought to a proper appreciation of the human factor in practical affairs.	This also is an advantage of the cooperative plan for which no adequate denial is found among the opinions collected. This factor would appear to be important in preparing students for the operating duties of industry.
The student learns business organization and procedure through	Two counter arguments are given to these statements:

actual observation and practice. He is brought face to face with the economic as well as with the technical side of engineering. The all-resident student, on the contrary, has little or no opportunity to learn business organization and procedure since there is little time available for such instruction in the undergraduate curriculum. Furthermore, it is very difficult, if not impossible, to teach such matters in the classroom.	First, that the types of positions occupied by cooperative students are of such a subordinate nature that little or no opportunity is afforded to learn business principles and methods. Second, that the graduate of the all-resident course learns these things during his introductory period in industry quite as well as he would under the cooperative plan; in fact, being more mature, he has a better appreciation of their importance.
The student observes and learns up-to-date shop practices and engineering methods.	Possibly he does. Does he, however, learn fundamental principles as well?

Advantages to the Student—Financial

The student is able to earn a large part of his expenses. Many young men are thus enabled to obtain an engineering education who would not otherwise be able to do so.	The great majority of engineering students work during their vacations. Rates of pay of cooperative students, particularly in their early positions, are small. Furthermore, industrial experience begins, in a majority of institutions, one or more years after admission. It is doubtful if, on the whole the cooperative student is any better off financially than is the all-resident student who works during the vacations. An important aspect of this matter which must not be overlooked is that graduation of the cooperative student is deferred one year (cooperative courses are usually of five years duration, all-resident courses four years). The advent of the cooperative student to full-fledged employment and financial independence is therefore postponed, a serious matter in many individual cases and undesirable in general.

Salaries of cooperative graduates exceed those of all-resident graduates.	This claim is not backed by evidence. (Data presented in this report, see pages 590 to 592 incl., do not substantiate the claim. It is true that the figures show greater earnings of the cooperative graduate immediately after leaving college and for a few years thereafter, but if equal age be made the basis of comparison, the graduates of the two courses are on an equal footing. The evidence presented is not conclusive, however, and until adequate information is available, claims of the superior earning ability of one group or the other ought not to be made.—Ed.)
The student establishes a demand for his services. It is easier to place cooperative than all-resident graduates.	Again, the facts do not substantiate the contention. The demand for graduates of all-resident courses exceeds the supply. Industries which recruit technically trained personnel systematically do not distinguish between graduates of the two types of courses.
The period of apprenticeship of the graduate in industry is reduced and his promotion is more rapid.	An answer to this assertion is furnished by the statement of the Director of Personnel of a firm which employs large numbers of graduates and has systematically recruited and trained them for years. He stated that the all-resident graduate is as far along in his company's organization one year after leaving college as is the coopérative graduate upon leaving college, or farther—the two men then being of the same age. This is true, however, only if the cooperative graduate has spent his industrial periods with the company in question. If industrial experience was acquired with another com-

	pany, the cooperative graduate starts on exactly the same basis as the all-resident graduate. Thereafter there is no discernible difference in their rate of advancement.

Advantages to the Institution and Faculty

With given facilities and staff, more students can be accommodated. The cost per student is thus reduced. The resources of the institution are made available to a larger number. Certain shops and laboratories can be eliminated or reduced, thus further reducing the cost.	If students take the same number of hours of instruction in sections of the same size and if the teachers carry the same teaching loads, the cost of instruction will not be different in the two cases. If it is different, the student either takes less work or the teacher does more without corresponding increase of compensation. From observation, the latter seems to be the case. Overhead expenses of administration, upkeep of buildings, and the like are less in the cooperative system but this saving is offset by the cost of maintaining a corps of coordinators. The investment per student in buildings and equipment however is reduced. This is a matter of great economic importance.
The cooperative student returning from his periods of industrial experience is more discerning and rationally critical of the work of his instructors. The faculty is, therefore, forced to keep abreast of current practices and does not get into a rut. The cooperative student, through his greater appreciation of the value of his education, is more of a challenge and an inspiration to his teachers.	On the other hand, the faculty is under the burden of repeating instruction to alternating sections of a class. This increases the monotony of instruction and tends to accentuate the tendency to get into a rut. Furthermore, the staff is engaged during eleven months of the year (in most colleges operating on the cooperative plan). There is less opportunity for independent study and research and the teacher tends to become a purely routine task-bearer. The statements of teachers indicate

	that the intensive nature of cooperative courses, as practiced, places increased burdens on the faculty and that this is one of the serious disadvantages of the plan.
Close relationships are established between the institutions and the industries. A basis of mutual appreciation of educational and industrial problems is thus afforded which is of great benefit to the college.	Equally intimate and valuable contacts can be maintained through other means; in particular through members of the teaching staff who serve industry directly in consulting and advisory capacities and through research carried out for the benefit of industry. Such activities are inhibited under the pressure of the cooperative system.

Advantages to Industry

An opportunity is afforded to try out the students, to observe their ability and traits of character and to choose those of greatest promise for permanent employment. The students are more easily assimilated into the organization and are inculcated with a spirit of loyalty to it.	This may be true, but is it always for the student's best interest? Is there not danger that the organization may exploit the students to its own advantage?
Cooperative students may be placed with small industrial concerns which do not see the necessity or advantage of employing engineering graduates. Such firms are educated to the value of technically trained personnel and of scientific methods, and are thus included among those benefiting from the results of engineering education.	Why need this result depend upon the cooperative plan? Is not the same thing going on steadily throughout all industry whether or not the cooperative method furnishes the entering wedge?
Industries have found it more difficult to obtain suitable personnel for the operation of plants and processes than they have to obtain competent designers. The coop-	If this be granted, is it not possible that the development of this side of the student will make him less competent on the more strictly technical side of his work?

erative plan furnishes men having a background of experience and point of view which is indispensable in the line of operating duties. Engineering graduates will be required more and more in the future for work of this character.

Disadvantages to the Student

Against the Plan (*Statements of Opponents*)	*For the Plan* (*Statements of Advocates*)
The length of the college course is increased and the advent of the student to productive employment is deferred.	On the other hand, the student both produces and earns while he is in college, thus offsetting any disadvantage of deferred graduation. Furthermore, the length of the cooperative course is not greater than that of all-resident courses in several institutions.
Cooperative courses operate under higher pressure. Students carry a larger load of classroom instruction. There is an undesirable ''high degree of concentration in the curriculum'' and insufficient time for non-technical subjects. There is less time for study and reflection and for the process of ''unconscious assimilation.''	These objections are not inherent in the cooperative system but only in the way it is conducted in some institutions. They can be removed under proper handling just as readily as in the all-resident system.
Intermittent instruction causes undesirable breaks in class work. Continuity of the learning process, which is indispensable to proper educational results, is impossible. There is loss of time due to interruption of instruction and the student must readjust himself to college work upon each return from industry.	Teachers of cooperative courses testify that the fear upon which this contention is based is groundless and that alternation of classroom and industrial work affords a rest from the steady grind of college which results in greater mental activity and increased efficiency.
The cooperative plan interferes with participation in college activities which are a valuable phase of	On the other hand, the student forms contacts outside of college and his interests are thereby

college life; in fact, many of the desirable activities cannot be carried on at all.	broadened. Furthermore, administrative arrangements may be made so that participation in athletics is not interfered with.
There is danger that the student may become saturated with the idea of commercial success to the exclusion of broader cultural interests.	This is pure nonsense.
The eleven-month year of the cooperative course provides very little time for vacations and no single vacation of any considerable length. This is especially undesirable for students whose homes are at a distance. During the entire five years it would not be possible for them to be at home more that a few days and only then at great expense in proportion to the time spent with their families. This is a condition to which students and parents alike can justly object.	This would affect an insignificant number of students, since engineering colleges draw their students from a comparatively small radius (for statistics on this matter see Bulletin No. 1 of this series, pages 5, 6 and 29). Students seriously affected by this phase of the plan need not enroll in it. It is not contended, except by a very few. that the cooperative plan should be established in all colleges or required of all students.
The cooperative plan does not afford sufficient opportunity for the development of the student's social side. Contacts with fellow students, particularly those in courses other than engineering, and participation in social activities are, in general, one of the valuable aspects of college years. They serve to give the student poise in his social contacts and to prepare him for that side of life after graduation. Engineers are often said to be lacking in this respect. The cooperative course tends still further to emphasize this deficiency.	This is a mere assertion. Cooperative students participate as fully in college life outside of the classroom as do other engineering students. Furthermore, contact with men outside of the college assists materially in developing the student's social poise.
Under the close supervision of the cooperative system the student is likely to lose a sense of reliance	If this danger exists it should be guarded against. Placing the student in industry should not.

upon his own resources and to expect as a matter of course that institution and employer will provide him with a suitable position upon graduation. In a word, there is danger that the cooperative system may exercise too much paternal control.	however, have this effect. In fact, one of the distinct advantages of the cooperative plan is that it takes the student out of the regime of strict supervision by the faculty, and places him much more largely on his own resources in industry, where he is likely to see clearly that success depends upon his own initiative.

Disadvantages to the College and the Faculty

Depressions in industry affect student employment and may seriously interfere with the success of the plan.	The cooperative plan has weathered such depressions.
Employing concerns dominate the situation. There is seldom a choice of positions and the college is not able to select those providing proper experience.	It is entirely possible for the college to meet such difficulties. Industrial experience may be made subordinate to educational aims if properly organized and administered.
The administration of cooperative courses is more complicated and difficult than that of all-resident courses. A special corps of coordinators should be employed, thus entailing additional expense.	If the plan has merit, its adoption should not hinge upon matters of administrative difficulty. Any additional expense of the staff of coordinators is more than offset by increased revenue and the greater number of students accommodated.
If the institution has other departments operating on the all-resident basis, it is difficult to coordinate the instruction of the two groups of students. This is especially difficult when engineering students are enrolled in the same sections with students of other courses, as they often are in mathematics, English, chemistry and other subjects.	In such institutions the instruction of engineering students may be given entirely within the engineering department under a completely separate faculty. Or, if this is not practicable, alternation between college and industry may be arranged on a term or semester basis and all conflict with the schedules of all-resident students avoided.
It is very difficult, if not indeed impossible, to arrange for vacations of the teachers other than very short periods arranged on a	This is another argument which does not apply to the plan per se, but only to the way it is conducted in certain of the institutions. The

"catch-as-catch-can" basis. This is extremely undesirable from every standpoint, and is testified to by teachers of cooperative courses as one of the serious objections to the plan.	situation can be remedied by proper planning and the teachers given all the vacations really needed.

Disadvantages to Industry

The cooperative student is a liability during his periods of industrial experience and actually costs the industry money.	Employers are glad to procure cooperative students. Even if the student does not produce in proportion to his wages, the employer gains through obtaining graduates better adapted to his organization.
If all or a considerable number of colleges adopted the cooperative plan, industries could not absorb the students without serious interference with their operation.	Approximately 17,000,000 persons are employed in American industries, exclusive of agriculture. Compared with this figure the number of cooperative engineering students is insignificant.
Other employees, particularly foremen and superintendents, object to the presence of cooperative students and to the necessity of supervising them and of "breaking in" new lots of students at regular intervals. This upsets shop routine and decreases efficiency.	This may be true when cooperation is first undertaken, but it has been learned by experience that other employees soon adjust to the conditions and thereafter find no objection to the plan.
In some lines of engineering work continuity of attention on the part of the man handling the work is absolutely essential. In such work it would not be possible to have two students alternate on the job. This excludes the cooperative plan from positions in which really valuable experience could be required.	This applies only to certain types of work in certain engineering fields and is a condition of such limited application as not to be a serious detriment to the cooperative system as a whole or to its application in any of the major engineering fields. The number and variety of positions available to cooperative students, when all of the positions to which this objection applies have been subtracted, is amply sufficient to supply all of the needs of the cooperative system both as to kinds of work and value of experience afforded.

C. Testimony of Employers

Sources of Testimony.—A number of representatives of firms employing cooperative engineering students were named by several of the college administrators as qualified to express opinions on the merits of cooperative engineering education. Letters were sent to 44 of these firms; 29 replies were received, a few being incomplete. Their experience is based on the following periods of years and upon the number of engineering students indicated:

Length of Experience with Cooperative Students		Number of Cooperative Students Employed at Present	
Years	Firms	Students	Firms
1	7	1 to 5	10
2	4	6 " 10	6
3 to 5	4	11 " 20	6
6 " 9	5	21 " 30	3
10 " 14	6	31 " 40	3

Character and Purpose of Industrial Work.—Half of the firms which replied reported that work is not assigned to a student primarily with the idea of assisting in his engineering education; only one replied that it is, adding that the work is the same as that given to graduates who are being trained for the company's work. Six firms stated that the assignments are not primarily to aid the education of the student; but some of these firms stated that they try to give him varied experience; others, that they do not include common labor; etc. One concern gave as a primary object its desire to assist students in a financial way. Twenty of the firms stated in substance that the cooperative student is a profitable employee, two that he is not; one reported that it could make him profitable but that the student would then be the loser.

Almost all of the firms consider it essential, for the period of alternation employed, that the students be paired to maintain continuous service at the plants. To quote one opinion: "Our students are paired, and the time in each department is so planned that we are never short of a man. This we believe is quite essential, and the foreman does not have to break up a machine crew to take the place of an absent student.'' For longer periods of alternation, fewer concerns deem pairing essential.

Questioned on the real value of the work given to cooperative students in promoting college engineering education of the highest type, representatives of thirteen firms said that the work offered in their plants has real value, one that it has not, and the others gave various opinions. On the other hand, ten replied that the work offered in their plants simply makes it easier for the graduate to fit into industry; seven others agreed to this, adding that it does more; one asked if this is not what engineering education is for.

Employers Favor the Plan.—To test the sentiment for and against the cooperative system of education, the three following direct questions were put to the representatives of industrial firms with results as summarized under each:

a. ''Would you like to see more engineering colleges adopt the cooperative system?''

Nineteen answer *Yes,* one *No,* two are not sure, one doesn't care, and three do not answer. One large firm states that since only one-quarter of the students remain with it, more of them mean greater economic waste for it.

b. ''Would you like to see all colleges adopt the system?''

Eight answer *Yes*, eleven *No,* one is indifferent and nine make no reply or are indefinite.

c. ''Would you be just as well satisfied if the cooperative movement died out? That is, are you satisfied with the type of engineering graduates from colleges not using the cooperative system?''

Twenty-one answer *No* with varying degrees of emphasis, three are uncertain, two express indifference, and one says *Yes.*

It must be remembered that the replies summarized above were given, in general, by the individuals charged with the handling of cooperative students while in industrial employ and that these individuals as a whole might naturally be expected to view the cooperative system favorably. It does not follow that the same results would have been obtained by canvassing other officers of the employing firms. Even with this reservation, however, it must be concluded, in general, that firms employing cooperative students endorse the plan as having educational merit. The fact that they continue cooperation with the colleges after a fair trial of the plan substantiates this conclusion.

Quotations of Opinions.—Some interesting opinions on these questions are given below:

> "I think some form of the cooperative system could be employed to advantage generally; provided, the length of the engineering courses could be increased accordingly. In other words, the time spent in industries should not be allowed to count as time spent in the laboratory or classroom. I do not think that the cooperative system without this additional time would be applicable to schools for advanced engineering. Possibly the cooperative system would keep some 'misfits' out of engineering."

> "As a personal opinion, I believe that either an engineering college should be based on the cooperative plan wholly, or it should not undertake it at all. The cooperative plan should reach a class of students that could not afford a regular four or five year college education. I believe that industry can obtain men from both sources to advantage."

> "Personally I think an uninterrupted four year college training is preferable to the cooperative plan. I consider that the latter plan affords an opportunity for college training to a class of young men who would not be able to devote four years to undergraduate work because of the heavy expense. I am inclined to think that the industrialist would withdraw his cooperation if too many colleges should enter the cooperative field."

> "We are not fully satisfied with the general run of engineering colleges not using the cooperative system, or to put it another way, we find that in almost every case, natural ability being equal, the young man who has had the opportunity of a cooperative course is absorbable sooner and at a higher rate than the man who has not had the same training but has yet to have adjusted his attitude toward work and industry, and the relation of his education to practical work. This adjustment is the hardest job industry has to do,—to adjust the state of mind of the college man. When this can be satisfactorily accomplished, the rest is easy."

> "Graduates after a year's experience old style are not equal to cooperative graduates. I believe the most competent man is the correspondence school man who completes his course, next to him is the cooperative student. If the man lacks the determination for these more difficult methods, I suppose he should receive his education in ease and luxury."

> "Engineering students from non-cooperative colleges are just

as satisfactory. The principal benefit of the cooperative system to our organization is the fact that we can have students whenever we want them. We can also pick out the most likely students, thereby insuring a better class of helpers than we could secure anywhere else. The best ones are then retained after graduation if they desire to remain with us.''

''A student who is willing to work to obtain his education will appreciate both his education and his job. Am heartily in favor of the cooperative plan.''

''Undoubtedly, for certain types of men, this (cooperative) is the best kind of training, although we believe that this type of training is of more value to the men who go into practical work than into employment where theoretical work is the first consideration.''

''I must say that some of our best men have come from the non-cooperative type of college.''

''The movement could die out, for the good engineer is not dependent on the cooperative system. The good engineer should have practical experience along with theory and ability, but cooperative work is only one method of getting practice.''

''This system could be adopted in more colleges and be of benefit providing that the men were sent to work in plants that would be able to use the men when they graduated. At present we are deriving no real benefit from employing the cooperative student but we are helping to supply the demand from other concerns. We know that this is so because the men when they graduate always seek employment elsewhere.''

''I am satisfied that both are needed and that both have a field and obligation to society and industry.''

''Unless the school, the industry and the student have some general, definite plan in mind, I do not think the maximum benefits will be obtained in cooperative courses. There should be no semblance of the indentured apprentice scheme, or promise to remain, because I do not think that would be fair to any of the parties concerned. However, unless all the parties concerned are training to some rather definite end, the maximum benefits will not result.''

''One of our divisions tried to get all Cincinnati students this year. I am not quite sure of the figures, but I think they are as follows: Of forty-eight graduates, forty remained with the industry for which they were working. The other eight, for one reason or another, wanted to change to some other industry. Our division could get none of the eight. This is not entirely because they fit into industry so smoothly, but because they are very much higher grade engineers, and the demand is going to be many times the supply for quite a number of years to come.''

D. Summary and Conclusion

The following paragraphs summarize briefly the inferences and conclusions which seem warranted by the foregoing statements of fact and opinion.

Educational Merits.—As a means of imparting the fundamental principles of science and engineering, the cooperative plan has not been shown to be either superior or inferior to the ordinary all-resident plan. If any inference is warranted, it appears to be that the two systems, *when conducted equally well,* produce equally meritorious results, though not of identical character. On the one hand there is no proof that the effort to coordinate industrial experience with instruction received in college results in greater learning efficiency or a better grasp of fundamental principles. On the other hand, proof is equally lacking that the discontinuity of instruction associated with the cooperative system results in any discernible decrease in educational efficiency.

Until more complete and conclusive evidence is available than that afforded by the facts thus far compiled, herein or elsewhere, or by the sweeping statements of opinion made both by the advocates and the opponents of the plan, judgment upon the scholastic merits of the cooperative system should be suspended.

Character Development.—Without attempting fully to discuss the cooperative plan from the standpoint of character development, the indications are that it should be credited with tending to develop, through actual trial, the student's stamina, resourcefulness, and sense of responsibility at an early age. In a word, the cooperative system provides a steadying influence which tends to mature the student. Some may feel that this is not wholly desirable. The college student is likely to be something of an idealist and to have a rather well developed sense of altruism. This attitude toward life, if properly fostered in college, is likely to carry over into years of maturity and leave a wholesome residuum to act as a balance to the sophistication of later life. The cooperative plan which advances the time of entry into the competitive atmosphere of industrial experience, may hasten the process of converting the idealist into the realist. This, in the last analysis, may not be an end wholly to be desired.

Orientation to Industry.—It can hardly be denied that the cooperative plan provides a means of acquainting the student with the importance of the human element in practical affairs. Periods of industrial experience should give the student an insight into the reactions and point of view of the working man and thus equip him better to deal with the labor problems which he is likely to encounter in later years. Further, the cooperative plan seems unquestionably to offer the means of valid vocational guidance; actual trial being probably the one sure way of determining aptitude and liking for particular lines of work. The conclusion also seems warranted that the assimilability of the student to industrial organizations is increased, in fact this aspect of cooperative training is pointed out as one of its greatest merits by the employers of students and graduates.

Preparation for Operating Side of Industry.—The attributes of the cooperative plan in developing particular personal traits and points of view, together with the orientation to industrial organization which it affords, would seem to indicate that it is particularly advantageous as means of developing personnel for the administrative and operating side of industry. This, indeed, seems to be the peculiar merit of the system which is indicated most clearly. And it is by no means an unimportant one. The results of other studies in the general investigation of engineering education * show that a large (and probably increasing) proportion of engineering graduates are entering corporate employ and sooner or later occupying positions concerned chiefly with operating duties. American industry seems to be turning more and more to the engineering colleges for recruits to man the operating side of its organizations. If, as seems likely, the cooperative plan offers even a partial solution to the problem of training men for these positions, it undoubtedly possesses merits of very great importance.

Economic Aspects.—The economic aspects of the cooperative plan deserve careful consideration. It is clear that more students can be accommodated with given physical facilities. Just how large an increase is permitted depends upon several factors, including, the period of the curriculum at which cooperative training begins and ends, the length of the academic year, distribution of enrollment by classes, and the proportion of time devoted to college and to industrial work. On the average, it is probable that from 33 to 50 per cent more students can be accommodated under the cooperative plan when used throughout the entire course. This results in a reduction of capital expenditure per student and is a matter of great importance. The costs of higher education are high and probably are increasing. Engineering education is one of the most expensive forms of higher education.* Any plan which offers a means of reducing capital expenditures without decreasing the effectiveness of the educational processes warrants the most serious thought of all concerned.

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* See particularly Bulletins Number 3 and 8 of this series.

From the standpoint of the student desirous of going to college but without sufficient funds to pay all of his expenses, the cooperative plan is undoubtedly attractive since it guarantees him an opportunity to earn a substantial part of his expenses. Offsetting this advantage there is the added time required to complete the undergraduate course. If five years from date of admission to college be considered and allowance made for the earnings of the all-resident student during vacations and during the first year after graduation, there is little difference in the total earnings of all-resident and cooperative students.

Other claims of the financial advantage of the cooperative plan are not wholly substantiated. In particular it seems probable that the lower cost of operation, and especially of the lower cost of instruction which obtains in some instances, are due to the intensive manner in which cooperative courses are commonly operated and to added burdens on the teaching staff, rather than to any intrinsic features of the plan.

It is obvious, of course, that if the same tuition be charged per year in five-year cooperative courses as in four-year all-resident courses, additional revenue is obtainable from this source. This has been mentioned as one of the financial advantages of the cooperative plan.

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* See Bulletin Number 6 of this series.

Causes of Growth of the Cooperative Plan.—It may probably be seriously questioned whether much of the growth of the cooperative plan has not been due to its attractiveness in reducing the investment in facilities and in providing for the self-supporting student rather than to its fundamental educational merit. To institutions considering the establishment of engineering courses or already providing such courses without adequate resources, the cooperative plan seems to offer not only the means of reducing initial outlay but also of insuring a student body and of increasing the revenue from tuition fees. Neither of these motives ought to be criticized, provided always that the cooperative plan does not serve as a disguise for insufficient facilities, for an inadequate and overworked teaching staff, and for low educational standards generally. It is to be feared that this has been the case in some instances and that much of the real merit of the cooperative system, when pursued under the proper circumstances, may be lost sight of because of the manner in which it is sometimes conducted.

Relationship of the College to the Community.—One aspect of cooperative engineering training not mentioned specifically in any of the discussions of correspondents but which seems worthy of attention is what may be termed "the integration of the institution with the community." Since it offers a means of serving students who might otherwise not be able to attend college and also provides a direct relationship of undergraduate work with the activities of industrial concerns, the cooperative plan would seem to bring the institution into closely articulated relationship with both the homes and the commercial and industrial activity of its community. It may be that this apparently direct service to the municipality, whether explicitly recognized or not, has been a factor in the adoption of the cooperative plan by a number of municipally supported institutions and also by those institutions which, while not directly subsidized by the municipality, nevertheless have a close relationship with it. This phase of the cooperative plan undoubtedly has publicity values which urban institutions might, and in some instances do, capitalize.

The Non-Graduating Student.—Another matter to which attention may be directed is the value of cooperative courses to the student who is unable to complete his course. As pointed out in Bulletin No. 2 of this series, approximately five of every eight students admitted to engineering courses fail to graduate. The problem of providing as much as possible of value to these students is a very serious one, applying as it does to a majority of those admitted. It would seem especially appropriate for publicly supported institutions to consider it carefully. Some advocates of the cooperative plan point out that cooperative courses serve as a natural selective process in which the student continues to the point which his natural ability, purposefulness, and aptitude for industrial pursuits qualify him to achieve; and that he then steps off into regular employment with a background of both academic and industrial training of an extent proportional to his ability and to the type of position that he is qualified to fill. This is a contention which, obviously, it would be very difficult fully to substantiate; it would seem to be largely an ideal rather than completely an actuality. Nevertheless there seems to be an element of justification for it in the conception and principles of the cooperative plan as well as some basis for the belief that the system does tend, at least, to produce the results claimed. If so, it is a feature which should be duly weighed in any appraisal of the cooperative system.

Practical vs. Philosophical Values.—The summarized statements of the opinions of those canvassed do not touch upon the important question of whether cooperative training serves as well on the more philosophic side of the student's education as it does on the side of the practical and the concrete. A scheme of life which keeps the student at assigned work throughout practically the full academic calendar year, alternating between study and practice at fairly short intervals, and which in some cases adds to the intensiveness of the scholastic schedule, can hardly be expected to promote reflective thinking. Contacts with the practical concrete problems and with the hard-headed supervisory personnel of industry are fairly certain to develop the student's ''horse sense'' and counteract his tendency to seek involved ways of doing simple things. This result is excellent as far as it goes, but there is a likelihood that constant emphasis on practical knowledge and empirical judgment may lessen the student's respect for more abstract knowledge and react unfavorably on the development of his higher analytical powers and his capacity for generalized thinking. How largely these suppositions are true, what relative emphasis may best be given to the two types of training, both good, and what preparation leads to the highest ultimate development, are likely to remain speculative questions for some time. Forty years of experience, rather than twenty, may lead to a more decisive verdict.

Conclusion.—Cooperative engineering training has passed through an initial experimental period and is now firmly established in the general field of engineering education in the United States. It has been adopted and is working successfully in several of the strong institutions of the country. This fact alone, if there were none other, is proof that the plan has merit and deserves a recognized place in engineering education. On the other hand, few except the most ardent advocates of the system will probably hold that it should be adopted universally. It is a plain fact that all-resident curricula in engineering, though they are certainly open to improvement, are, in general, successful in accomplishing their purposes. Neither all students nor all institutions, nor all types of engineering services, are best served by a single, uniform, standardized type of program. The field of engineering is immensely broad. Engineering graduates function throughout its entire range from the executive management of huge industrial enterprises and from professional services of the most expert character on the one hand to minor types of technical and operating services on the other. In this diversified field cooperative training seems unmistakably to have its proper place. The indications are that its particular function and peculiar merit is in training men for the operation of industrial enterprises. That many young men pursuing cooperative courses will become highly competent designers or researchers, and that many all-resident students will attain to positions of importance in the operating side of industry is undeniable, but it is probable that the cooperative program tends, on the average, more directly to prepare students to adjust themselves promptly to the requirements of administration and operation.

PART IV. BIBLIOGRAPHY

Although the cooperative plan has been in operation in this country for twenty years, there have been very few careful and specific discussions of it in print. The most comprehensive bibliography on the subject is given by Clyde W. Park in his ''The Cooperative System of Education.'' The present bibliography, which applies to articles which have been published in the United States, was compiled after an examination of all of the 104 items listed by Professor Park and a number of others found by a search of the files of the publications of the various engineering societies, of the Proceedings of the Society for the Promotion of Engineering Education, and of the United States Bureau of Education. A search has also been conducted through the Engineering Index and the Index to Periodical Literature. It is quite possible that certain articles have escaped detection, though it is believed that the important American ones have been included.

In the present instance it was thought advisable to depart from the usual custom of listing all titles relating to a given subject, and instead to give only those of such importance as really to warrant the reader's attention. All discussions of industrial education in general, articles referring to cooperative education in the secondary schools, those which are merely brief comments, those whose subject-matter has been gathered up and embodied in later articles, and others which seemed unimportant have been discarded. The shortness of the list which remains attests the fact that the literature on cooperative courses is not nearly so extensive as the importance of the subject would seem to warrant.

For the reader's convenience in selecting articles for reading or study, the bibliography herein given, in addition to listing the titles and the sources from which publications may be obtained, presents a brief summary of the more important features of each article. It is hoped that this descriptive feature of the compilation will add to its usefulness. Since the usual arguments in favor of the cooperative plan are stated, at least in part, in almost every discussion of the subject, and since these arguments are fully and admirably presented in Professor Park's booklet, they are in general omitted in the synopses of the articles listed below.

Anonymous. "COOPERATIVE RAILWAY ENGINEERING COURSES: CENTRAL OF GEORGIA RAILWAY AND GEORGIA SCHOOL OF TECHNOLOGY WORKING OUT AMBITIOUS PROGRAM." *Railway Age:* Vol. 77, No. 21, Nov. 22, 1924, pp. 921–924. (Illustrated.)

The Georgia School of Technology offers both all-resident and cooperative courses. This article presents several of the usual arguments in favor of cooperative courses. Physical requirements for admission to the cooperative courses are stringent, owing to examinations conducted by the Railway. Students work in the Central of Georgia Railway shops and alternate with resident instruction at four-week intervals. They cover as much ground in theory while in college as the regular students. It is said that they cover it more intelligently. The Railway endorses the cooperative plan. The article was written when the plan was in its second year.

Alexander, M. W., and Jackson, D. C. "REQUIREMENTS OF THE ENGINEERING INDUSTRIES AND THE EDUCATION OF ENGINEERS." *Mechanical Engineering:* Vol. 43, No. 6, June, 1921, pp. 391–395.

A valuable discussion of the educational philosophy underlying the cooperative plan of engineering education, particularly from the standpoint of preparation for industrial experience. Reasons are given for the adoption of a cooperative curriculum in electrical engineering by the Massachusetts Institute of Technology under an agreement with the General Electric Company. The following digest of the article appears as an introduction in the publication above mentioned.

''A combination of empiricism and training in rational science is needed in engineering education because it is needed in the engineering industries, and this consideration has led to various plans for placing engineering students within the influence of industrial operation, the most common being for engineering college graduates to enter industrial establishments as 'cadets,' 'engineering apprentices' or 'student engineers.'

''The first comprehensive, organized plan for bridging the gap between academic and practical training of the young engineer was made operative in the United States in 1906 when Herman Schneider, Dean of the Engineering Department at the University of Cincinnati, organized a cooperative engineering course in connection with the metal-manufacturing plants of that city. Schneider's ideas lie at the base of the cooperative plan which the authors succeeded in organizing a few years ago in connection with the Massachusetts Institute of Technology and the Lynn Works of the General Electric Company, and which is described at length in the present paper.

''This cooperative engineering course covers a total of five years, the first two being identical with the freshman and sophomore years at the Institute and the last three being divided between instruction in theory at the Institute and instruction in practice at the Lynn Works. In these last three years the total time occupied in studies at the Institute and practice at the Works is eleven months per year. The first term of the cooperative period, extending through thirteen weeks, is spent at the Works by all of the students during the summer period immediately following the sophomore year at the Institute. The succeeding terms of similar duration are spent alternately by each half of the student group at the Institute and at the Works, while the final term is spent by all the students at the Institute for additional advanced instruction and the preparation of a master's thesis prior to the college commencement.

''During their assignments at the Lynn Works, students are subject to the usual rules and regulations applying to employees of the General Electric Company, and on a full week's work schedule receive compensation at the rate of $21 per week at the beginning of the course and $24 at the end.

''The joint supervisory committee of the two institutions believe that this experiment in cooperative engineering training will exert a most beneficial influence upon the relationship of the engineering college to industry and upon the activities of each. They are clear in their own minds, however, that the cooperative training in engineering must not and cannot replace the regular engineering courses at colleges which in the nature of things must cater to the majority of young men seeking a thorough training in the engineering sciences, and many of whom do not enter the manufacturing industries. The cooperative training, however, is destined to become a vital integral part of a comprehensive system of engineering education, to the detriment of none of the other parts, but to the mutual benefit of all, and is particularly important to the manufacturing industries of the nation.''

Alexander, M. W. Discussion of Timbie's ''COOPERATIVE COURSE IN ELECTRICAL ENGINEERING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.'' *Journal of the American Institute of Electrical Engineers:* Vol. 44, No. 10, Oct., 1925, pp. 1128.

Two features of the cooperative course described by Professor Timbie might with profit be adopted by any educational institution:

First, since in the cooperative course, the college year is increased from thirty-six to forty-eight weeks, the entire course might be completed in three years. The year saved, if put to useful employment, would enable the student to acquire actual experience and hence integrate himself in industry. Or, if the year saved should be devoted to further study, his education might be deepened in the basic sciences of engineering and broadened in the general subjects.

Second, cooperative courses fix the student's mind on application of principles to practice, thus giving him a true perspective for his theoretical and scientific work. This is a lesson which those who do not adopt the cooperative plan might learn.

Cincinnati, University of.

Articles on the cooperative plan as practiced at this institution; arguments for the plan, its purpose, methods, results, etc., have been numerous within the past fifteen years, and have been published in various periodicals devoted to engineering as well as in the popular periodicals. The authors in the main are connected with the university, notably Dean Herman Schneider and Professor Clyde W. Park. The substance of almost all of these articles and studies is presented by Professor Park in the one comprehensive study listed under his name in this bibliography. It comprehends, supplements, as well as supersedes, all that was written on the subject prior to its publication.

Faig, John T. "THE EFFECT OF COOPERATIVE COURSES UPON INSTRUCTORS." *Engineering Education:* Vol. 3, No. 7, March, 1913, pp. 493–502.

Based on the experiences of instructors at the University of Cincinnati only. States that the types of cooperating industries affect academic schedules and the subject-matter of various courses; that practicing engineers, executives, foremen, etc., have a beneficial influence upon instructors by their suggestions and their reports of students' progress; that cooperative students influence instructors by their requests for information of a practical nature, by their interest in certain subjects, and by their reflection of the attitude of workmen in the industries.

Hallock, J. W. W. "THE COOPERATIVE PLAN OF ENGINEERING EDUCATION." *Engineering Education:* Vol. 8, No. 1, Sept., 1917, pp. 12–24.

Gives features of the cooperative plan and its workings at the University of Pittsburgh. None other than cooperative courses are offered in engineering. Cooperation begins with the sophomore year. Periods of alternation are three months. An outline is given of the duties of the Director of Cooperation; blanks for foreman's report and names of cooperating firms are also given. The outstanding advantage claimed for the plan is that it forestalls the apprentice period. Stories of typical student cases are given. Several objections to the plan are stated, but in general it is given hearty endorsement. Reports from alumni graduated under the cooperative plan indicate a highly favorable attitude toward it.

Kolbe, Parke R. "THE PART TIME PRINCIPLE IN EDUCATION." *Educational Review:* Vol. 50, Nov., 1915, pp. 348–359.

A statement of the arguments in favor of part-time education in the professions, with incidental application to engineering. A clear and cogent presentation of underlying principles.

Matheson, K. G. "COOPERATIVE ENGINEERING EDUCATION." *Engineers and Engineering:* Vol. 39, No. 11, Nov., 1922, pp. 384–386.

Many institutions have established non-commercial shops in order to coordinate theory and practice. Objections to this policy lie in the excessive expense of keeping equipment up to date and lack of time for adequate shop practice. Worcester Polytechnic maintains a commercial shop; Antioch College proposes to establish such shops. The University of Cincinnati plan is a feasible solution of the problem. A description of the plan is given. The cooperative plan was established at the Georgia School of Technology in 1912, and was successful, union laborers in the industries making no objection. The University of Akron, Georgia School of Technology, Lafayette College, New York University, University College (Boston), Massachusetts Institute of Technology and Harvard University practice the cooperative plan, and Drexel Institute proposes to establish it. Arguments in favor of the plan, which are presented, are said to be overwhelming.

Park, Clyde W. "THE COOPERATIVE SYSTEM OF EDUCATION." *University of Cincinnati Studies,* Series II, Volume XI, Part I, 1925. (A reprint of bulletin No. 37, Series of 1916, U. S. Bureau of Education, with additions.) 102 pp. Illustrated. Bibliography.

This bulletin presents the entire history of the cooperative system of education at the University of Cincinnati, the first institution to practice it in America, together with its purposes, methods, development, results; it includes tables of curricula in various courses in detail, report blanks, work sheets, office records of students, specimen work reports, description of courses, statistics of enrollment, etc., etc. It is a complete and highly satisfactory statement based on the experience of an institution that has practiced the cooperative plan for almost twenty years and has found it satisfactory in its results.

This account of the cooperative system is by far the most complete and elaborate yet attempted, and is indispensable to any investigator of the subject. It is too long to summarize even briefly and, indeed, is so full of valuable matter that it should be read completely and with care. While it presents only one side of the subject (nothing is said to indicate that any arguments may be advanced against cooperative education), it strikes the reader as an honest statement. Its survey is limited to the University of Cincinnati; there is no attempt at a comparative study.

Roe, Joseph W. "THE COOPERATIVE PLAN OF ENGINEERING EDUCATION." *Management Engineering:* May, 1922, pp. 269–274.

This seems to be the only truly comparative study of the cooperative plan that has appeared in print. It begins by discussing five plans of engineering education (a valuable synopsis), the fifth being the cooperative plan, traces the origin and growth of the plan at the University of Cincinnati, and then outlines the working of the same plan, or modifications of it, at the University of Akron, Antioch College, Northeastern University, Georgia School of Technology, University of Cincinnati, Harvard University, Marquette University, New York University, Massachusetts Institute of Technology, and the University of Pittsburgh. Tables are given to show the growth in numbers in the cooperative courses and comparisons and made between these and the numbers in the regular courses. Four diagrams show the length of the periods of alternation between the college and industrial periods at several institutions. The author states that the cooperative plan is not uniformly successful, the success being dependent upon the quality of coordination. He outlines the qualities desirable in a coordinator and outlines his duties. He states that the experience of employers is favorable to the cooperative plan.

Sackett, R. L. "DEVELOPMENTS IN COOPERATIVE ENGINEERING COURSES: A REVIEW OF THE VARIOUS ALTERNATE INDUSTRY AND CLASSROOM COURSES GIVEN IN DIFFERENT AMERICAN COLLEGES." *Engineering News-Record:* Vol. 90, No. 24, June 14, 1923, pp. 1050–1051.

Presents brief accounts of the cooperative plan as practiced at the University of Cincinnati, Massachusetts Institute of Technology, New York University, Harvard University, and Antioch College. States the obvious advantages of the plan as they are presented by all of its proponents. Also states the disadvantages at some length, and insists upon them: among others that the cooperative student (*a*) is largely deprived of participation in college activities; (*b*) has little time to cultivate college spirit; (*c*) is encouraged by the very nature of his training to take a materialistic attitude toward life—a tendency that education ought to counteract, not foster; and (*d*) maintains that the entire cooperative scheme places cultural education—that is, really professional education—in jeopardy, by making a complete sacrifice to industry. Pennsylvania State College meets the demand for practical training without sacrificing anything essential. "We are firm in our belief that it is not our province to give trade training, and that we are responsible for a broad cultural course, with a professional outlook; that we are responsible for thorough instruction in the fundamentals and for planting such standards of life in the minds of students that they will be able to serve society according to their capacities, to enjoy their work, and to use their leisure to advantage."

Smith, H. B. Discussion of Timbie's "COOPERATIVE COURSE IN ELECTRICAL ENGINEERING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY." *Journal of the American Institute of Electrical Engineers:* Vol. 44, No. 10, Oct., 1925, pp. 1127.

The author asserts that the closer the contact between industry, engineering organizations and the colleges the better the product of the colleges. A discussion is presented of a modification of the Cincinnati plan practiced at the Worcester Polytechnic Institute. Students leave the Institute at the end of their junior year for a period of fifteen months devoted to organized industrial experience, returning at the end of that time to complete the work of the senior year. Fifty students have pursued this course, only one of whom failed to return to complete the college course and obtain the degree. Experience with the plan has been favorable from the standpoint of the Institute.

Timbie, W. H. "DISTINCTIVE FEATURES OF A COOPERATIVE COURSE IN ENGINEERING." *Engineering News-Record:* Vol. 85, No. 3, July 15, 1920, pp. 119.

An account of the cooperative course in electrical engineering offered jointly by the Massachusetts Institute of Technology and the General Electric Company. Covers much the same ground as Professor Timbie's later article (listed below) and the article by Alexander and Jackson (listed above). The General Electric Company cooperates in training students; the length of time spent by the student in each department of the company is regulated solely by the value of the experience to the student, not by the needs of the department. Careful provision is made for the continuity of theoretical and humanistic studies, including liberalizing reading and the study of English in various phases.

Timbie, W. H. "COOPERATIVE COURSE IN ELECTRICAL ENGINEERING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY." *Journal of the American Institute of Electrical Engineers:* Vol. 44, No. 6, June, 1925, pp. 613–617.

The following synopsis appears as an introduction in the publication listed above.

"There is no standard cooperative plan of education. A cooperative course takes on the ideals, purposes and standards of the school and companies cooperating.

"The purpose of the Massachusetts Institute of Technology is to give young men well grounded knowledge and specialized information combined with a broad education and the power to apply theories of science to the practical requirements of industry. The cooperative course in electrical engineering at M. I. T. naturally has the same ideals and purposes.

"The course is five years in length and offers a degree of Master of Science to those who complete it. Only the last three years are cooperative, the first two years being practically identical with the regular electrical engineering course.

"The regular school year consists of two terms and a summer vacation. The cooperative year includes the summer in its schedule and has three terms to the year, two of them being coterminous with the regular Institute terms. During the last three years the cooperative students spend every other term (practically five months) at the plants of the cooperating companies, any one student always going to the same company. The practical experience thus occupies eighteen months of carefully selected and supervised work in the industries. The student has the choice of a manufacturing company or a public utility company, providing he meets the Institute standard in scholarship and the company's standard in personality and natural inclination. He is paid at an hourly rate depending upon his length of service with the company, each student earning about $1,500 during the three years. The last year is spent upon post-graduate study and research both at the Institute and with the company. The student is under no obligation to stay with the company after graduation nor is the company obliged to hire him. To date, 47 per cent of the men have remained with the cooperating company.

''While at the plants of the cooperating company, the student continues to carry two of his Institute studies, two evening classes per week being conducted by members of the instructing staff at the Institute.

''Main features. 1. The course aims to train a carefully chosen group for engineering service of the particularly high order, in manufacturing and public service companies.

2. The theoretical part of the regular electrical engineering course has not been cut in order to make room for the engineering practice. On the contrary a year of postgraduate work has been added, for which a degree of Master of Science is granted.

3. The engineering practice for a student consists of a course of experience, carefully planned and supervised. It is not merely a series of jobs.

4. The student spends all of his cooperative periods in the employ of one company getting a unified conception of organi-

zation and company policy. He learns the meaning of team work and loyalty.

5. Fluctuating business conditions do not interfere with his engineering practice.

6. The practical experience reacts on his theoretical work, explaining it and making it real to him.

7. His theoretical studies are not interrupted during his practice periods. He gets the habit of working days and studying nights, a habit which experience proves is hard to break in later years.

BULLETIN NUMBER 13
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

OPINIONS OF PROFESSIONAL ENGINEERS CONCERNING EDUCATIONAL POLICIES AND PRACTICES

A Summary of Inquiries by
The American Society of Civil Engineers
The American Institute of Mining and Metallurgical Engineers
The American Society of Mechanical Engineers
The American Institute of Electrical Engineers
The American Institute of Chemical Engineers

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The American Society of Civil Engineers
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Prefatory Note.—This Bulletin is arranged in two sections. The first, which comprises Parts I, II, and III, is based on all five inquiries and relates to engineering education in general. It includes a summary of general inferences and conclusions, a summary of opinions on a group of specific educational issues, and a summary of opinions concerning the extent and means of the influence of the engineering profession in engineering education. The second section comprises Parts IV to VIII inclusive and is devoted to the results of the inquiries which bear upon the several major divisions of engineering education, and to selected comments from each group of engineers.

PART I. INTRODUCTION AND SUMMARY OF GENERAL INFERENCES AND CONCLUSIONS

Purposes.—One of the major purposes of the general investigation of engineering education, conducted by the Society for the Promotion of Engineering Education from 1924 to 1927 inclusive, has been to prepare the way for a larger participation of the professional organizations of engineers in shaping the policies and practices of engineering education. As a definite step in that direction, the national engineering societies which correspond to the five major divisions of engineering education were invited to cooperate with the Board of Investigation and Coordination in conducting a group of special inquiries in order to ascertain the views of influential engineers on certain questions of present moment in engineering education and to gauge, both directly and by inference, the readiness of the profession as an organized body to exercise a share of responsibility for educational standards and processes. The principal inquiries were made through five questionnaires of the same general type, but with certain differences of detail to adapt each to the interests of the group addressed.

In addition to formal answers to definite questions, free comments of a more qualitative nature were sought under each of the heads and on the subject of engineering education in general. Many of these comments are of special value in revealing attitudes and shades of opinion. Certain data were also gathered from the personnel records of two of the participating societies in order to estimate the extent to which the engineering profession is dependent upon the colleges for the recruitment and training of its members.

Auspices.—Acknowledgment is due to the five professional societies which cooperated in the conduct of these inquiries, and individually to their national secretaries and the active representatives of the five committees through which cooperation was effected.

The American Society of Mechanical Engineers,
John Lyle Harrington, Chairman of Special Committee,
W. L. Durand, Secretary of Special Committee,
Calvin W. Rice, National Secretary.

The American Society of Civil Engineers,
Anson Marston, Chairman of Special Committee,
Harold M. Lewis, Secretary of Special Committee,
George T. Seabury, National Secretary.

The American Institute of Electrical Engineers,
Harold Pender, Chairman of Committee on Education,
Frederick L. Hutchinson, National Secretary.

The American Institute of Mining and Metallurgical Engineers,
William Kelly, Chairman of Special Committee,
W. B. Plank, Secretary of Special Committee,
H. Foster Bain, National Secretary.

The American Institute of Chemical Engineers,
H. C. Parmelee, Chairman of Educational Committee and National Secretary.

The inquiries were conducted in the order indicated above. The returns were compiled, analyzed and edited by the Staff of the general investigation. The material here presented is the result of the detailed compilation and complete statistical analysis of nearly eleven hundred returns, each dealing with a considerable number of items, and including both formal opinions and supplementary comments. The judgments on each point were weighed with careful regard to shades of opinion. In all the opinions summarized and the inferences drawn the editors have endeavored to set forth without bias the consensus or variety of judgments of the groups of engineers canvassed in the five inquiries. Graphical forms of presentation are employed throughout the Bulletin in place of statistical tables wherever practicable, with a view to greater vividness and to economy of space and attention.

Persons Consulted.—For the purposes of these studies the opinions of selected groups, representing the more influential men of the profession, were considered to be more significant than a random sampling covering all grades of professional standing and attainment. The lists to be canvassed were chosen with the advice of the committees and secretaries of the several societies in quotas roughly proportional to their respective memberships. The high calibre of the men consulted may be judged from the several summaries covering their education, responsibilities and types of activity to be found in Parts IV to VIII inclusive. Educators were included in relatively small proportions; since the opinions of teachers had already been canvassed in other inquiries, it was considered that the opinions of men of affairs should have the greater weight in this instance. The uniformly high proportions of replies received and the thoughtful quality of the opinions expressed indicate that the issues presented were given serious consideration. Taken as a whole, the summaries which follow are believed to be adequately representative of the mature judgment of the profession.

The numbers of persons canvassed and the returns received, by professional groups, are indicated below:

	Canvassed	Replied		Recorded	
Civil engineers (A. S. C. E.)	538	359	66.9%	327	61.3%
Mining engineers (A. I. M. E.)	306	177	57.8%	152	49.6%
Mechanical engineers (A. S. M. E.)	510	257	50.4%	239	46.9%
Electrical engineers (A. I. E. E.)	515	325	63.1%	271	52.6%
Chemical engineers (A. I. Ch. E.)	100	70	70.0%	69	69.0%
Total	1,969	1,188	60.3%	1,058	53.7%

The differences between the number of replies received and replies recorded are due in part to late returns and in part to the fact that some returns were in forms which did not admit of statistical compilation.

Issues Considered.—The specific questions concerning educational requirements and practices which were dealt with by questionnaires, fall under eight heads:

1. The fundamental elements which should be included in the education of all engineers.
2. The degree of differentiation between the programs of studies in the major divisions of engineering.
3. The extent and character of specialization within the major divisions of engineering.
4. The fundamental basis of differentiation of curricula; whether to accord with the major technical divisions of engineering, as at present, or with functional types of engineering activity.
5. The extent to which training in administration and management should be introduced into undergraduate curricula.
6. Training in economics and the economic aspects of engineering as an element in engineering programs.
7. The value and use of modern foreign languages.
8. The nature and extent of instruction in shop practice and in surveying.

The second group of questions dealt with matters of broad policy rather than questions of educational practice and was concerned specifically with the issue concerning the influence of the profession, through the national societies, upon engineering education, and the means to be employed to that end.

General Inferences and Conclusions

The Attitude of the Profession toward Education.—The engineering profession in America has never formulated a policy concerning the recruitment and training of its future members. Its guiding traditions, largely inherited from British sources, have been those of an open profession entered through a novitiate of practical experience, to which formal scientific training is a desirable but optional auxiliary. While these traditions are firmly maintained in principle, in reality they have been largely reshaped by changing conditions. Forty years ago less than a quarter of the members of national engineering societies were college graduates; to-day more than two-thirds of those entering their membership hold college degrees and more than four-fifths have had a substantial amount of college training. The profession at large has accepted these changes passively. Probably it has not yet attained to the stage of unity and self-consciousness where it might attempt a formal shaping of educational policy. For the present it seems that its policy must be implicit, to be inferred from the general state of opinion.

Provisional Statement of Principles.—The data of these studies, more than any other body of material yet gathered, reduce the attitudes of the profession at large to an orderly basis for a provisional statement of educational policy. For the sake of simplicity and order, the broader inferences supported by these data are set forth as a series of propositions, with modifying comments:

a. Engineering is an open profession, accessible to both self-educated men and men of formal scientific culture. College training has become the normal first step to professional standing, but engineering education can not be reduced to a scholastic process alone. Experience in subordinate capacities under the direction and criticism of qualified practitioners is an indispensable part of the training of engineers.

b. Engineering is a broad function in social economy with varied types and grades of responsibility. Its personnel includes a well marked professional nucleus, with which are closely associated auxiliary and subordinate groups forming a natural vestibule to professional status and constituting a considerable proportion of the whole. To accord with this diversity, engineering education should include a variety of types and institutions ranging in character from the vocational to the professional. No single procrustean program, as in medical or dental education, can meet these varied needs.

While no explicit opinion was asked concerning the proper length of engineering college training, the replies tacitly accept the four-year undergraduate program as a norm for the great body of students; the need of many students for shorter and more intensive vocational curricula is pointed out in several comments; many specifically advise post-graduate work as the proper place for specialization; a moderate number strongly recommend an academic college course as a desirable prelude to engineering study; and a few urge that a pre-engineering program of this type should be required in all cases.

c. Engineering is concerned with technological, economic and administrative problems; it has an immensely ramified scheme of individual specialization along both technical and functional lines and is further subdivided by grades of responsibility. It is impracticable to reproduce this complex pattern in a workable scheme of formal education, nor can students make valid choices among the many fields of specialization. The schools should concern themselves with underlying principles; principles are best taught in connection with their applications; technical subjects proper should serve as media for teaching principles and the characteristic engineering methods of thought and analysis, rather than attempt to prepare for specific types of practice.

d. Engineers as a body hold to a highly realistic educational philosophy. In their judgment formal teaching in advance of responsible experience should be limited largely to the underlying principles of engineering, its methods of analysis, its verbal, graphical and symbolic language processes, and its setting in contemporary civilization. They deem it wise to bring instruction largely within the range of the student's personal experience and observation as extended by laboratory processes. They deem it impossible to reproduce engineering problems as a whole, with their inseparable economic and administrative complications, in the artificially simplified setting of a school. Professional preparation may be begun in a school, but must be completed in practice.

e. The principal curricula of the engineering colleges should be differentiated from each other to a moderate degree only, sufficient to assure concentration on a logically related core of subject matter and to bring the student's efforts to a focus in one of the major engineering fields. In general actual specialization should be postponed to the years after graduation, and be undertaken either in the graduate school or in connection with introductory experience.

f. The program of the engineering colleges should be built up on broad lines from humanistic, scientific and technological materials of a basic character. A self-contained program which may be entered direct from secondary schools should be provided for the majority under definite engineering auspices, but encouragement should be given to students who voluntarily undertake to extend the range of humanistic studies in a college of arts before entering upon the study of engineering. A substantial core of English and economics, of mathematical and physical sciences, and of subjects which develop the scientific bases of engineering technology should form the common foundation of all undergraduate curricula.

g. Relatively few institutions should undertake to provide special training in specific fields of engineering practice, and this training should be largely in post-graduate courses. There should be considerable specialization among institutions at this stage, according to advantages of personnel, environment and equipment.

h. The economic aspects of engineering, as well as its technological aspects, deserve considerable emphasis in all engineering subjects. Engineering students should be given some introduction to the problems of administration and management, but no attempt should be made to give specific training for executive positions.

i. The quality of engineering education is determined primarily by the qualifications and effectiveness of teachers and the preparation and aptitude of students, rather than by curricula and equipment. Teachers should have both scholarly preparation and professional experience and should be in active touch with engineering practice. As far as practicable students should be selected for aptitude as well as scholastic attainment.

j. The engineering profession, through its national societies, should share in responsibility for shaping the programs and standards of engineering education. There is a substantial plurality of opinion in favor of giving formal recognition, in admissions to membership and the support of student branches, to institutions which meet or exceed reasonable minimum standards in their requirements for admission and graduation and in the qualifications of their teaching staffs.

PART II. EDUCATIONAL REQUIREMENTS AND PRACTICES

A. Fundamental Elements to be Included in the Training of All Engineers

The first question of each questionnaire was substantially the same:

"What subjects in addition to Mathematics, Physics, Chemistry, Drawing and English should be included in all curricula in the major divisions of engineering (Civil, Mining, Mechanical, etc.)?"

To facilitate answers, each questionnaire form included a list of the usual subjects and of others frequently proposed as desirable additions or substitutes. The lists were not identical in every case, but were quite similar in their essential particulars. Spaces for checking selections were provided, as well as blank lines on which additional recommendations could be entered. The returns from the five groups are shown graphically in Fig. 1. The judgments of the several groups are not entirely free from certain characteristic biases. For example, civil engineers hold surveying in high esteem for all students and give a low rating to shopwork; while chemical engineers give surveying a very low rating and exceed other groups in their esteem for foreign language. Taken in combination, however, the rankings given the various subjects stand as a fairly decisive verdict on the much mooted question of fundamentals.

It is of interest to compare the rankings of the fundamental subjects by these groups, in which practitioners largely predominate, with the rankings made by a group of more than five hundred engineering professors, as shown in Fig. 2.[1] There is a striking conformity in the majority opinions of

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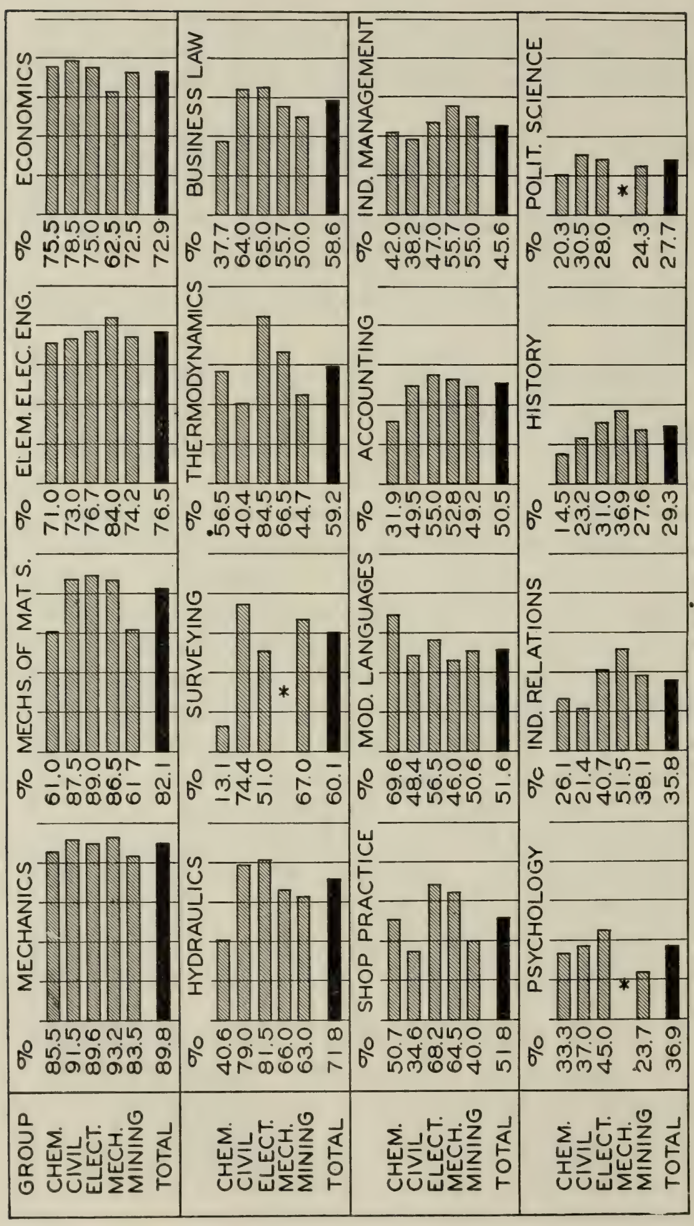
[1] See Bulletin No. 9 of this series, p. 399.



* NOT INCLUDED IN QUESTIONNAIRE

FIG. 1. Subjects to be included in all engineering curricula, in addition to Mathematics, Physics, Chemistry, Drawing, and English; the percentages of the several groups of engineers who recommend each subject are indicated.

the two groups. The engineers consistently favor business and societal subjects more highly than the teachers, but the teachers are probably more restrained by knowledge of the time limitations of the college program in recommending additional subjects for inclusion.

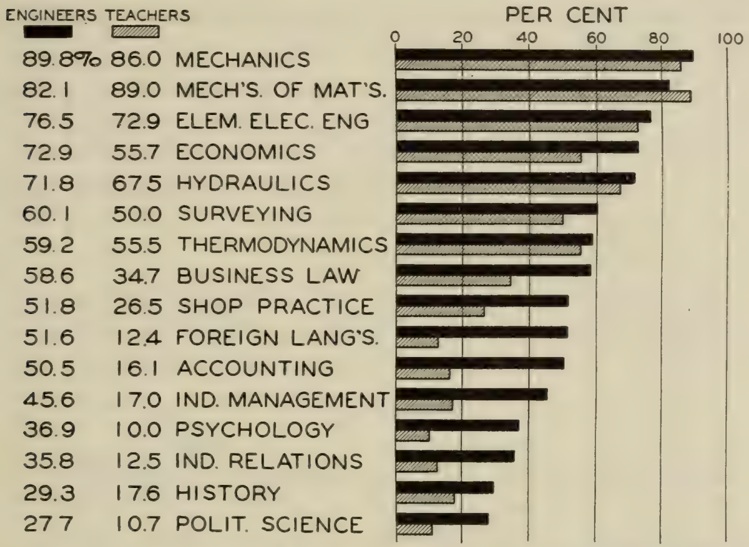


FIG. 2. Percentages of professional engineers who recommend basic subjects "for inclusion in all engineering curricula," and of engineering teachers who consider these subjects "of primary importance."

The subjects on which both groups are strongly agreed appear to embody a solid and coherent foundation for an education in any field of subsequent specialization. When the rankings of the subjects are compared with present curricula, the most striking contrast is between the high ranking given to economics and the relatively small provision for this type of instruction in many engineering curricula. This discrepancy is doubtless due in part to a lag in the adjustment of curricula to new conditions and emphases in the work of the profession, but it appears to be due in larger measure to the difficulty which many institutions experience in obtaining a treatment of the subject which is realistic and significant to engineering students.

B. DIFFERENTIATION OF CURRICULA IN MAJOR DIVISIONS OF ENGINEERING

Each group was asked to indicate a preference as to the degree to which the curriculum in its own branch of engineering should be differentiated from those in the other major branches of engineering. The mechanical engineers expressed their preference as follows:

13.3 per cent favor a course *sharply differentiated* from those in other major branches of engineering,
71.0 per cent favor a *broader and more general course* with specialization in mechanical engineering subjects only to a minor degree,
15.7 per cent are non-committal.

The choice suggested to each of the other groups was between a *sharply differentiated* curriculum, a curriculum *moderately differentiated* or only so as to assure concentration on a logi-

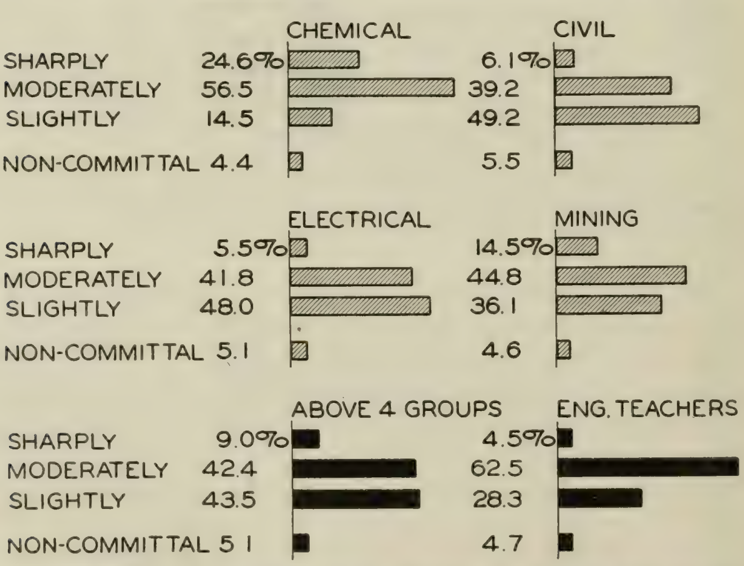


FIG. 3. Degree of differentiation between the principal engineering curricula recommended by groups of engineers and of engineering teachers.

cally related core of subject matter, and one *slightly differentiated* so as to give a broad and general engineering training. The judgments of the four groups are summed up graphically in Fig. 3, with the opinions previously expressed by more than five hundred engineering teachers[2] added for comparison.

Many of the engineers add comments to the effect that the curriculum should be devoted to fundamentals chiefly; a considerable number suggest that the last year be differentiated and an equal number advise that the student should specialize only after college or in the graduate school; others point out the inability of the average student to choose wisely; while a small minority set down a desire for more specialization quite pointedly.

There is a close agreement between the attitudes of both engineers and teachers, and those of a large body of graduates who are also on record:[3]

20.6 per cent favor broad training for the general needs of industry,
67.5 per cent favor broad training for the majority and specialized training for those who desire it,
11.9 per cent favor training for the needs of specialized divisions of engineering practice.

C. Specialization Within the Major Branches of Engineering

The problem of specialization was presented to the several groups by questions of somewhat different form. The replies are summarized in detail in Parts IV to VIII inclusive. In general only a minority approve of complete, distinct curricula in the principal subdivisions of the five major branches. A larger number favor group options in these subdivisions in the last undergraduate year, and many indicate that all such specialization should be deferred until after graduation.

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[2] See Bulletin No. 9 of this series, p. 391.

[3] See Bulletin No. 3 of this series, p. 240.

The replies to one question which had the same form in all the questionnaires may serve to indicate the general verdict on specialization. This question was:

"Should the instruction in the specific engineering subjects aim to prepare men for particular fields of work, or should they serve primarily as means of teaching fundamental scientific principles and engineering methods of thought and work?"

The replies of the five groups are summarized below:

	To Teach Engineering Principles and Methods	To Prepare for Particular Fields of Work	Approximate Ratio
Chemical engineers..........	92.8%	4.3%	22 : 1
Civil engineers.............	87.1	5.2	17 : 1
Electrical engineers..........	88.2	6.3	14 : 1
Mechanical engineers........	68.7	12.6	5 : 1
Mining engineers............	65.7	21.7	3 : 1

While all five groups are agreed in principle, it would seem that the mining engineers in particular, and the mechanical engineers to a lesser degree, attach relatively higher importance than other groups to the direct technical training afforded by the specific engineering subjects.

D. FUNCTIONAL VS. TECHNICAL DIVISIONS OF ENGINEERING CURRICULA

The original separation of engineering into military and civilian branches was essentially functional. Through evolution the civilian arm of the profession was subdivided progressively into the technical branches now known as civil, mining, metallurgical, mechanical, electrical, chemical, and the like, according to the type of scientific content and technical arts employed. In recent years the development of large-scale industrial organization has tended to lessen the emphasis on the technical divisions of engineering and to bring into prominence a new cleavage of functional activities under such heads as engineering research, design, construction, operation, management, and sales.

The basic plan of organization of engineering curricula has been technical for the last sixty years and more. A tendency has appeared in the past few years to add a new type of curriculum which stresses the managerial and commercial functions of engineering. Quite recently Prof. Edward Bennett has challenged the basic technical plan of educational organization with vigor and has proposed a sweeping reorganization along functional lines.[4] He holds that a regrouping of curricula along functional lines would be in closer accord with the differing abilities and tastes of students and with the actual types of engineering activity. The essential features of his proposal are two-fold: One is the provision of two types of treatment of the fundamental subjects of the early years, profoundly technical and moderately technical; the second is the provision in the later years of more extended and rigorous

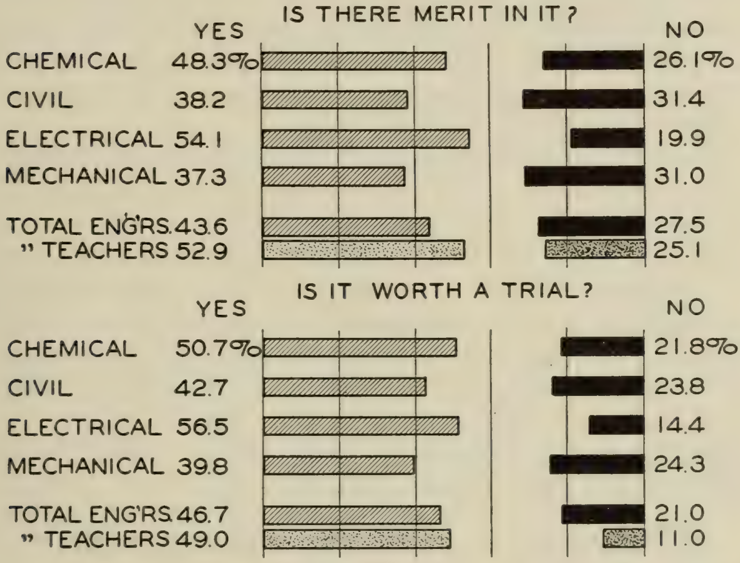

FIG. 4. Opinions of groups of engineers and engineering teachers concerning the proposal for a functional scheme of engineering curricula.

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[4] See JOURNAL OF ENGINEERING EDUCATION, June, 1924.

treatment of engineering subjects for the groups with more profound preparation and of less extended technical treatment with a broader handling of non-technical features of these subjects for other groups.

The several groups of engineers consulted, with the exception of the mining engineers, were asked to indicate whether or not in their judgment the proposed scheme of functional curricula *has merit* and whether or not it is *worthy of an experimental trial* in one or more institutions. The verdict as a whole is inconclusive, more favorable than adverse, though barely half recommend a trial of the plan. In consequence of the novelty of the proposition and the sketchy outline which could be given in small compass on the questionnaires, many preferred to remain non-committal. It will be observed that the teachers are somewhat more favorable to the functional scheme than the engineers in practice.

Much of the informal, written comment is strongly adverse to the plan; many assert that the student is incompetent to choose a program on functional lines; others, in a similar vein, hold that the choice involved would be premature and that the plan would fit only experienced men; a considerable number regard the plan as educationally objectionable and many doubt the feasibility of classifying the students on functional lines; many consider that the plan has some merit, but would try it out with great caution and not carry it too far. A small number of commentators lend vigorous support to the proposal and characterize it as a great educational advance.

E. Training in Administration and Management

As indicated in the foregoing section there is widespread discussion of the training to be given to engineering students in functional activities. There is especially active discussion of the extent to which instruction in administration and management should be introduced into undergraduate engineering curricula.

"Should specific training of this character be given in college? If so, should it be given to all, to many or to few stu-

dents of engineering, and should it receive major or minor emphasis in the curriculum?"

These issues were put to the mechanical engineers in a fairly general form, as described in Part VII, but in the later questionnaires sent to the other four groups these questions were presented explicitly and the opportunity given to express a choice between three or four methods of meeting the problem.

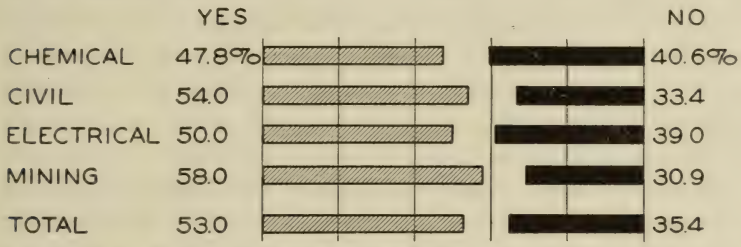

FIG. 5. Replies of groups of engineers to question, "Should specific training be given in administration and management?"

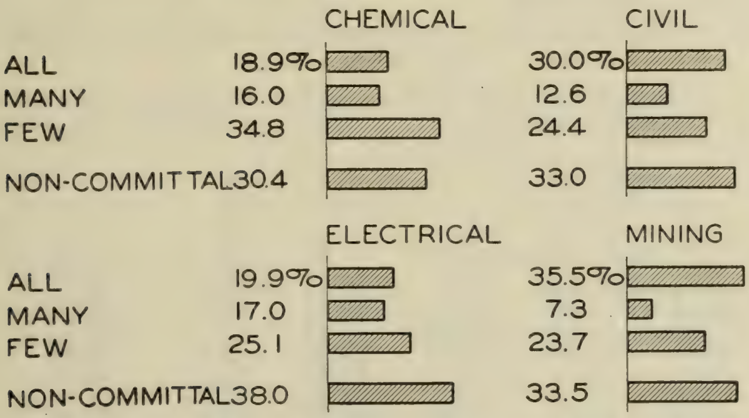

FIG. 6. Replies of groups of engineers to question, "Should specific training in administration and management be given to all, many, or few students?"

While the majority opinion clearly favors some specific attention to administration and management in the curriculum, to be available to the great majority of students, it also clearly favors keeping this type of instruction on a secondary plane of importance. The spontaneous comments entered under these questions are of particular interest. The opinions that experience affords the only real training, that administrators are marked by inborn traits and must be discovered by natural selection, that attempts to teach such matters in college are premature and detract from important essentials, and that these subjects are not soundly teachable, are stated with marked emphasis. Sixteen voice their protests against special curricula in administration in such terms as "fad," "humbug," "waste," "folly" and "bunk"; on the other hand eight urge the provision of a distinct curriculum in administration, though more favor such instruction as graduate work only. The great body of moderate opinion is clearly in favor of including some instruction in administration and management in the regular curriculum, as a secondary or elective subject, with the aim of presenting the problems of management and not that of attempting to train executives.

F. Training in Economics and the Economic Aspects of Engineering

In view of the universal concern of engineering with economic problems, all five groups of engineers were asked to

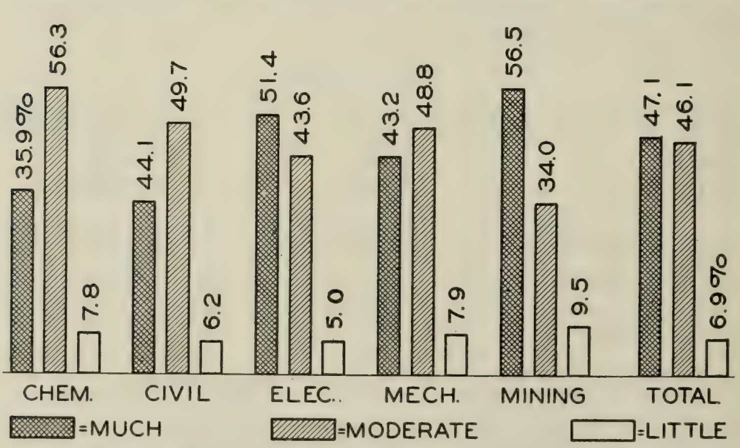

Fig. 7. Emphasis to be given to economics and to economic aspects of engineering in curricula and subject matter, as indicated by five groups of engineers.

indicate whether *much, moderate* or *little emphasis* should be given in the curricula and subject matter to economics and the economic aspects of engineering. The replies are highly consistent in placing the emphasis in the range from *moderate* to *much.*

All the groups were asked to indicate *whether or not they had found engineering graduates as well prepared to deal with the economic problems of engineering as with its technical aspects.* The mechanical engineers were asked this question with respect to graduates in general, but the question was divided in the subsequent inquiries so as to apply separately to graduates of less than five years' standing and those of five years' or more, in view of the frequent comment to the effect that ability of this type comes with maturity. The judgments expressed are strikingly consistent and point to a serious deficiency on the economic side which is only partially overcome through the training and experience gained during the early years after graduation.

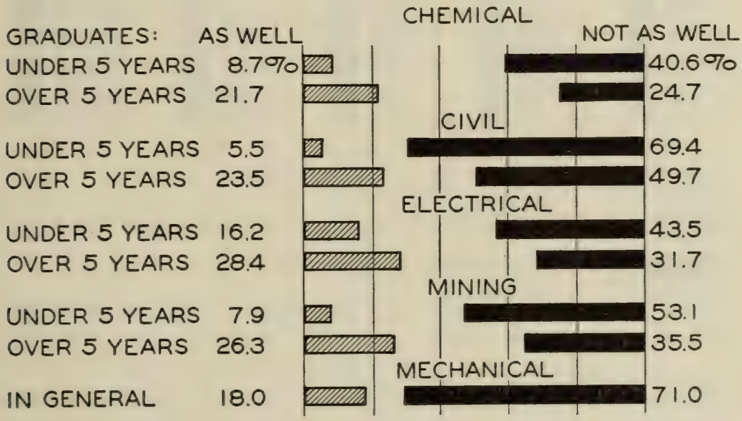

FIG. 8. Replies of groups of engineers to question, "Are engineering graduates as well prepared to deal with the economic problems of engineering as with its technical aspects?"

In pointing out the means to be taken to better this condition the majority of each group favor greater emphasis on the economic aspects of engineering in the engineering subjects proper; a substantial minority favor one or more subjects in the curriculum given by a special division concerned with the economics of engineering; while a somewhat smaller group comprising less than one-quarter of the whole favor additional work under a department of general economics.

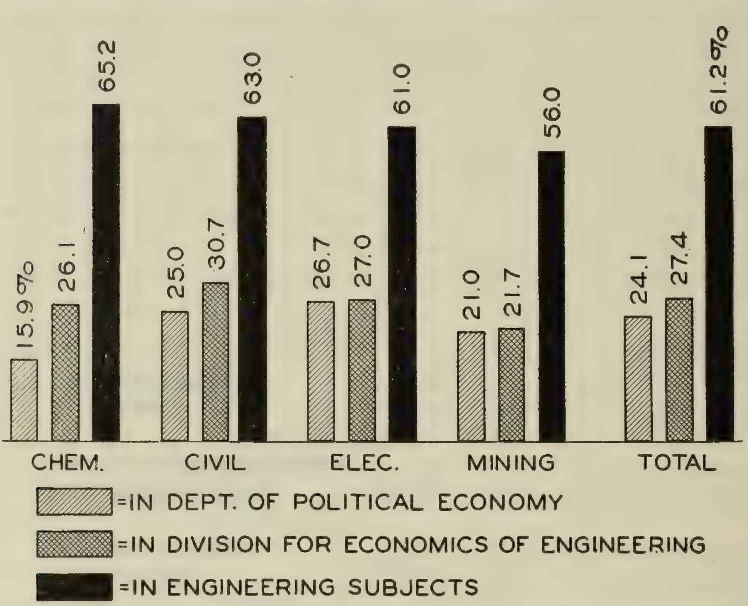

FIG. 9. Opinions of groups of engineers concerning the nature and place of measures to be taken to better the grasp of economic matters.

The supplemental comments emphasize the view that maturity and experience afford the chief basis of appreciation of and capacity to deal with the economic problems of engineering. Many state that the principles of economy are best dealt with concretely in the engineering subjects proper and by teachers with an adequate engineering background. A number express the view that the present scheme of instruction is inverted in its emphasis, overstressing the scientific and technical side of engineering at the expense of the economic. Few if any of the comments advise the omission of general economics, but a number characterize the usual presentation of the subject as ''inadequate,'' ''abstruse'' or the like. While the distinction was not explicitly stated in the wording of the questions, many of the commentators seem to accept *economics* as a relatively abstract science of wealth and *engineering economy* as a concrete effort to arrive at the best ratio of utility to cost. Most of the suggestions for improvement point distinctly in the latter direction.

G. THE USE AND VALUE OF MODERN FOREIGN LANGUAGES

One of the striking changes in engineering education during the past fifty years has been the declining attention to foreign languages.[5] Much of this decline has been attributed to the development of an abundant scientific and technical literature in the English language and to the lessened dependence of the modern engineer on foreign publications. Four of the groups of engineers were asked to indicate *the extent to which they have used foreign languages* in their business and professional activities, *which languages they have employed* and their views on the question:

''Are modern foreign languages, as generally taught to engineering students, justified by their cultural value in proportion to the time expended?''

The replies to the first question, as shown in Fig. 10, make it plain that the leading men of the engineering fraternity in America make relatively little use of foreign languages. As might be expected the degree of use is highest among the chemical engineers, who are still somewhat dependent on European publications for contact with the advances of the art The mining engineers probably stand first in the spoken use of foreign languages.

French and German stand out strongly as the languages in the greatest use, Spanish being of relatively high importance only to mining engineers. The estimates of the cultural value of foreign language as generally taught are highly consistent. They are shown in Fig. 12 and speak for themselves.

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[5] See Bulletin No. 11 of this series, p. 534.

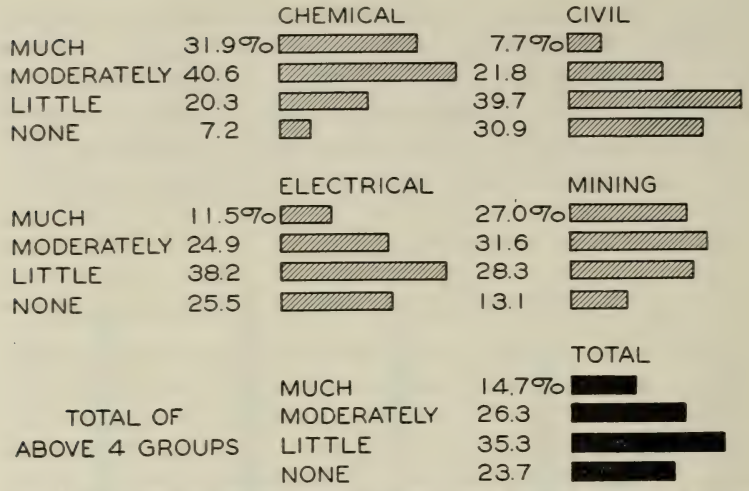

FIG. 10. Extent to which groups of engineers employ modern foreign languages.

The modern language question elicited numerous comments. Many state that language study is properly a part of preparatory education. Those who advise that the engineering student should get a working knowledge of at least one foreign

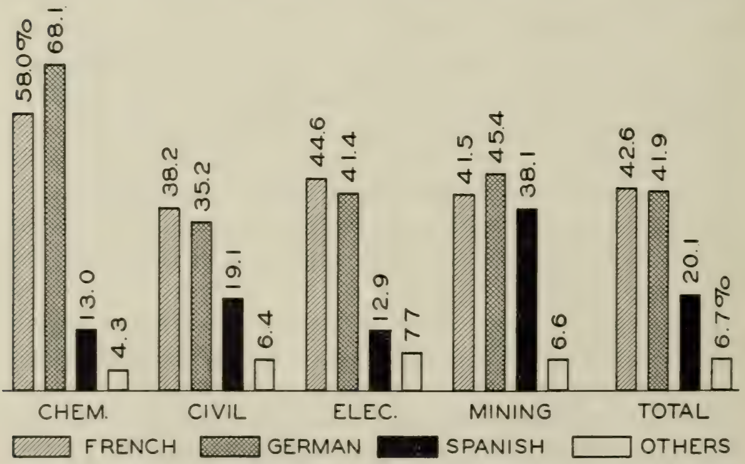

FIG. 11. Percentages of four groups of engineers who use the several foreign languages.

language stress facility in reading more often than ability to converse. German and French are suggested as desirable about twice as frequently as Spanish. Naturally, there is a body of comment definitely opposing required foreign language study in the engineering curriculum. Many frankly characterize such work as waste of time with the usual type of teaching. It is often stated that languages are not mastered well enough to be of real value and that the environment needed for their mastery is lacking in America. A number of comments voice a preference for other media of culture, many definitely advising that the time should be given to English and public speaking.

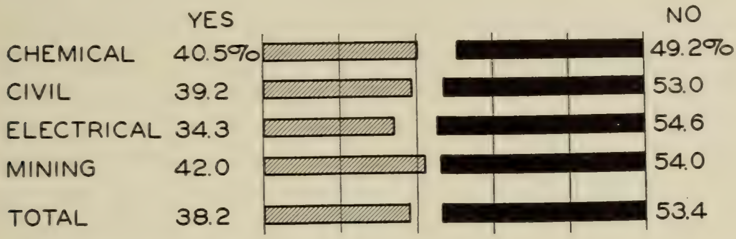

FIG. 12. Replies of groups of engineers to question, "Are modern foreign languages, as generally taught to engineering students, justified by their cultural values?"

Taken as a whole, the formal and informal opinions do not seem to place a value on the foreign languages which would justify their general retention as required work. A thorough reading knowledge of at least one language other than English, gained principally in preparatory work and extended where necessary through elective study in college, would seem to meet with general approval. Little can be said, however, in favor of scattering the student's effort among a number of languages without fair mastery of any. It is worth noting that a number of those who offered comments would place Latin on a par with the living tongues.

PART III. THE INFLUENCE OF THE NATIONAL ENGINEERING SOCIETIES IN ENGINEERING EDUCATION

Backgrounds.—The development of the engineering colleges in America has been almost exclusively an educational movement. The founders and directors of the schools have been educators by profession and only occasionally and incidentally active practitioners of engineering. Unlike the schools of medicine and dentistry which developed out of and finally displaced a scheme of pupillage, the engineering colleges have never been largely dominated by the professional body. They have been free to develop their educational service on broad lines, without being confined to the narrow boundaries of a strictly technical professional discipline. On the other hand, there has been little fostering of the schools by the engineering profession, no protection has been thrown around substantial standards and no moral influence has been brought to bear on institutions of uncertain quality. The engineering societies have not consistently recognized the work of the colleges as a substantial professional preparation; in one instance credit toward membership requirements allowed for graduation from an arduous four-year course is the same as that given for one year of experience in installing conduit and wire for an electrical contractor.

Significance of the Issue.—The engineers who sent in returns recognized the questions which dealt directly with the influence of the profession in engineering education as being of broad significance. The answers were evidently weighed with care. The comments which accompany them deserve careful appraisal as data of equal moment. Behind both the direct answers and comments stand the replies to the whole group of questions summarized in Part II. This body of opinion deserves to be recognized no less than the direct verdict on the issue, as an index of the desire of engineers to share in shaping the standards and processes of engineering education and of their capacity to deal constructively with the problems involved.

The Question of General Policy.—This question was formulated as follows:

"Should the engineering profession through the national societies, exercise a more direct influence in engineering education?"

Each individual was asked to frame a written opinion. There was no series of ready-made replies from which a choice might be checked. While the necessity for thinking out and formulating a reply was doubtless a factor in reducing the number of direct answers, a strikingly large number took the trouble to do it. In some cases a non-committal attitude doubtless reflected a state of unpreparedness to meet the issue or inability to visualize the means through which a favorable opinion might be given effect. If only the definite expressions of opinions are considered the ratio of those who favor a more direct influence to those opposed is practically nine to one.

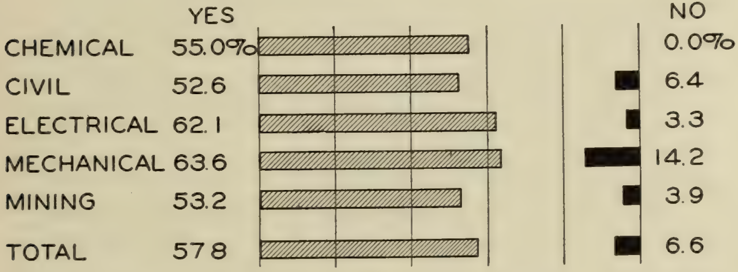

FIG. 13. Replies of groups of engineers to question, "Should the national engineering societies exercise a more direct influence in engineering education?"

Emphatic Endorsements.—There were many comments endorsing the proposal for a larger influence by the national societies in strong terms. A few representative samples follow:

> "I think this is one of the most important functions of the profession through the societies." (Consulting engineer)
>
> "As an employer of many chemical engineering graduates I have been convinced of the necessity for close cooperation between the engineering societies and the colleges." (Consulting engineer)
>
> "The engineering societies could not be engaged in a better or more laudable work. The societies are eminently qualified to serve and should exercise a direct influence in educational matters."
> (Consulting civil engineer)

"Yes. For the salvation of the profession."
(Consulting civil engineer)

"Emphatically *yes!* The profession can advance but poorly under the tutelage of inferior vision or cloistered technology."
(Construction engineer)

"Yes, in helping to develop some plan whereby such education, cost and effort is not wasted on poor material not qualified for engineering work." (Chief electrical engineer)

"I consider such cooperation necessary."
(Consulting electrical engineer)

"Yes. This is of vital concern to the future of the profession and the engineering societies should consider it a duty and obligation." (Consulting mechanical engineer)

"Very important not only for the profession but for the industries in general." (Vice-president, manufacturing co.)

"I believe the engineering societies can exert a profound influence." (Vice-president, manufacturing co.)

"Yes, it would be helpful and constructive."
(President, mining engineer)

"Yes, especially should this become a means of contact as between business firms and the colleges." (Dean, school of mines)

"The national societies should be the medium through which the engineering profession should attempt to promote and guide engineering education." (Research engineer)

"Certainly. If graduate coaching is good for athletics, why is it not good for engineering education." (Superintendent)

"The national societies should guide technical education with a strong hand." (Vice-president)

Guarded Endorsements.—On the other hand many comments sounded a warning against intrusion or imposed standardization and suggested that the influence of the national societies should be purely advisory. Examples:

"Yes, in helping us to estimate long time results and prospective needs. But, for the Lord's sake, don't presume to tell us how."
(Dean, engineering college)

"They might give advice but should not dominate or dictate."
(Metallurgical engineer)

"The A. I. M. E. may rightly act as a forum for the discussion of undergraduate education, but it should not take unto itself the official function of dictating or otherwise 'cooperating' in such matters." (Mining economic analyst)

"Not necessarily direct, but should exercise some real influence."
(Vice-president, coal and iron co.)

"Moral suasion. The Society is fussing with too many things."
(District manager, manufacturing co.)

"The influence should be to inspire and guide, not to dictate." (Editor)

"Advisory only—and then when asked." (Bridge engineer)

"If the engineering profession through the Societies indicates the qualifications or education necessary for a successful career, then the colleges through their professors will meet these requirements. This should be left to the colleges to work out." (Civil engineer)

"Difficult to avoid relations being perfunctory or else amateurish." (Manager, electric power)

"Should encourage and stimulate, but not dictate or attempt to dictate." (Personnel manager)

Adverse Comments.—Still another group gave voice emphatically to an attitude of "hands off:"

"Mind your own business. Don't meddle with things you don't understand. I have taught for fifty years and don't know much yet. How can you know if you haven't taught at all?" (Professor of mining)

"No. I do not believe this is the natural function of such societies." (Electrical engineer, railroad)

"The affiliation is already too close. It even now does much to prevent independent thought and action." (Consulting electrical engineer)

"It is impossible for the engineering profession to express itself through the national societies in a helpful way. The educators in the universities might just as well and as effectively seek to direct the engineering profession." (Chief municipal engineer)

"I feel that professional opinion is so unformed that it can have but little effect on the colleges." (Transportation engineer)

"Doubtful as to any closer relation. The fields of the schools and the societies are distinct and do not lend themselves to a great cooperation." (Geologist, steel company)

"No. All such questions should be left to experts." (President and gen. manager)

"The mass of the members will not participate and the activities will gravitate to the control of a small group of doctrinaires who will use the Society to promote their own notions." (Chemical engineer, lead co.)

Suggested Forms of Cooperation.—Many of the comments include incidental suggestions as to methods of cooperation between the societies and the colleges. A number of these are classified and tabulated below:

TABLE I

FORMS OF COOPERATION BETWEEN ENGINEERING SOCIETIES AND COLLEGES

	Chem.	Civil	Elec.	Mech.	Min.	All
An active Committee on Education in each society	1	16	15	8	4	44
Send able engineers to colleges as lecturers	1	6	7	1	6	21
Appoint engineers as advisers or as members of college boards	1	1	1	7	3	13
Chief contact through student chapters		8	5			13
Repeat inquiries of this type at intervals	2	3	2	5	1	13
Send official visitors to the colleges	1	1	3	2	1	8
Create joint national Committee on Education	1	3	1	3		8
Provide scholarships, prizes and medals		5	1	2		8
Get teachers to join the societies and attend meetings	1	2	2	1	1	7
Work through the S. P. E. E.		2	3	1	1	7
Encourage competent men to accept professorships	1	2	1	1	1	6
Get agreement on qualifications desired in graduates	1		1	3	1	6
Assist teachers to gain experience in practice		1	5			6
Recommend specialized portions of curricula			1	3	2	6
Have students get experience before graduation		1	4		1	6

In addition to the suggestions tabulated above several comments urge the societies to promote the cooperative plan, to help create and supply text material and data, to encourage the students to join the societies, and to link up the colleges with the sectional divisions of the societies.

Recognition of Colleges.—The national engineering societies participating in these studies enroll student members, maintain student chapters or branches, and grant credit toward membership requirements to graduates of ''approved'' or ''recognized'' engineering colleges.[6] The by-law regulations covering these activities are quite general in definition and scope and are applied by the officers of the societies in a confidential discretionary manner. As a result, the engineering profession has exercised practically no open influence in establishing or sustaining educational standards or in guiding the public to discrimination between sound, marginal and deficient institutions calling themselves ''colleges of engineering.'' Its position in this matter has differed markedly from that of other nationally organized professions, such as law, medicine, architecture and dentistry. It seemed pertinent to extend the general question concerning the influence of the engineering profession on engineering education into a more concrete issue:

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[6] The A. I. Ch. E. does not enroll student members and makes no mention of ''recognized'' colleges in its membership regulations.

''Specifically, and as one means of exercising a direct influence on engineering education, do you believe that the . . . (Name of Society) . . . should maintain and publish a list of approved institutions whose graduates would receive credit for a substantial part of the requirements for membership and in which student branches would be recognized?''

Following this question it was asked:

''If so, on what principle or basis should such a list of approved institutions be drawn up?''

A list of items was appended so that answers might be made by checking. The replies to the two questions stated above are summarized in Figs. 14 and 15.

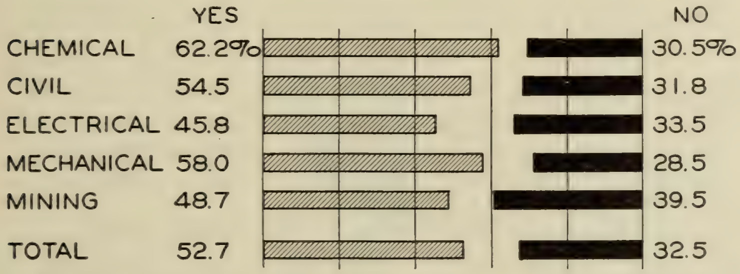

FIG. 14. Replies of groups of engineers to question, ''Should the national engineering societies maintain and publish a list of approved institutions?''

By comparing Fig. 14 with Fig. 15 it will be noted that the more concrete aspect of the problem with a choice of answers suggested resulted in a more definite taking of sides. The suggestion for a list of ''approved'' institutions is favored by a decisive plurality of each group and a small majority of the entire group. The ratio of approval to disapproval varies from a minimum of 1.24 to 1 in the mining group to 2.04 to 1 in the mechanical group, with a weighted average of 1.61 to 1 for the five groups.

Basis of Recognition.—The expression of opinion on the contingent question of the basis on which such an approved list should be drawn up was naturally confined almost exclusively to those who had indicated an approval of the plan in principle. The electrical engineers, however, registered more strongly on the particulars than on the principle. It may be noted that practically all who favor an approved list in principle favor basing it in part on the total graduation requirements; over ninety per cent favor giving weight to the

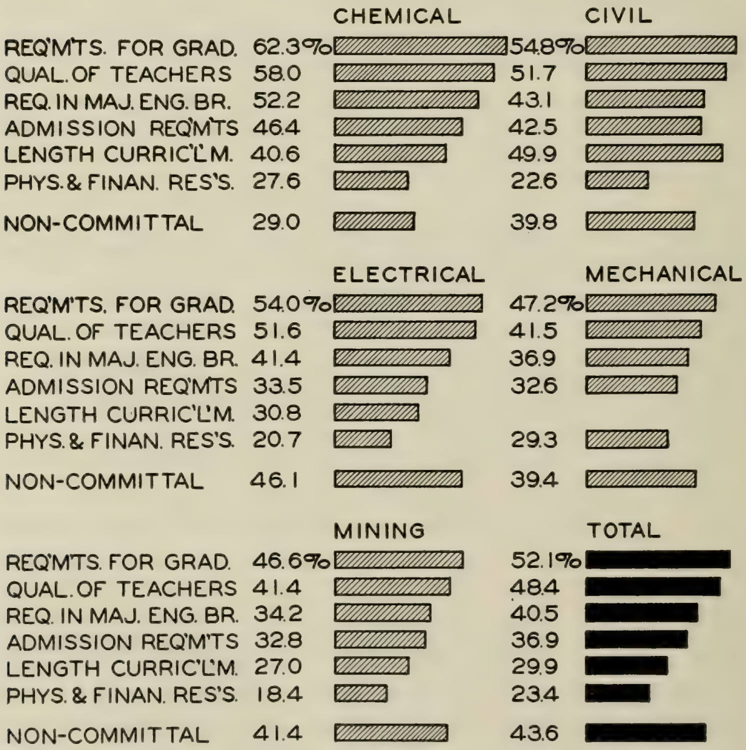

Fig. 15. Matters to be considered in drawing up a list of approved institutions, as recommended by five groups of engineers.

qualifications of the teaching staff, more than seventy-five per cent to the requirements in the major branch of engineering, and seventy per cent to the requirements for admission; but only a minority of those favoring the plan would consider the physical and financial resources of the institution. In short, a sound course of study and an adequate staff, and not endowment and plant, are ranked as primary qualifications.

Comments on an Approved List.—As might be expected, the questions relating to an approved list of institutions drew forth a large volume of comment. In the main three positions are taken, endorsement, endorsement of principle qualified by doubts of practicability, and emphatic disapproval. The questionnaires supplied no information concerning the rapid spread of weak or marginal institutions and the increasing proportion of the total enrollment in institutions of this character. Each person was left to estimate the degree of exigency for himself. The comments repeatedly strike the note, ''Consider the student, not the school.'' The opinion is often expressed that the selection of such a list of institutions would require careful investigation and great discrimination, that the societies are not at present set up to handle a problem of this nature, and that great care would be needed to keep such a list from becoming a mere routine and perfunctory matter.

Editorial Comment.—Considering the radical departure from the traditional policy of *laissez faire* which these proposals for the recognition of institutions involve and the admitted difficulties to be faced in putting them into effect, the favorable verdict seems to carry great weight. The successful handling of the matter would seem to call for close cooperation among the five societies of engineers and with the Society for the Promotion of Engineering Education as representing the colleges. There is no indication of a desire on the part of any of these bodies to impose a rigid standardization or classification of colleges such as exists in the fields of medicine and dentistry. Reasonable minimum qualifications for the recognition of an institution ''as a college of engineering'' to serve as a safeguard to the public and to the engineering profession, stand approved in principle.

SECOND SECTION—SUMMARIES OF SEPARATE INQUIRIES

In the following section are set forth in summary form the results of the inquiries which relate to the several professional divisions of engineering education. The facts concerning the qualifications of each group of engineers are given briefly, and selections from the general comments on engineering education as a whole. The professional divisions are presented in alphabetical order.

PART IV. CHEMICAL ENGINEERING

Engineers Consulted.—All but two of the sixty-nine replies summarized came from college trained men representing twenty-five American and several foreign institutions. Nearly forty-four per cent were trained in chemistry, nineteen per cent in chemical engineering, and the remainder in miscellaneous fields. The two largest groups, according to the type of practice, are in manufacturing and consulting respectively with more than thirty per cent each. Industrial executives make up thirty-six per cent, research engineers about twenty per cent and educators about twelve per cent of the entire group, the remainder being scattered under many heads.

Nature and General Content of Curricula.—The opinions of chemical engineers included in the graphical tabulations of Part II may be summarized as follows. The curriculum should be fairly distinct from those in other major branches of engineering in order that adequate grounding in chemistry may be given. It should be broad in scope and include foundation studies in mathematics, physics, general chemistry, English, drawing, mechanics, economics, modern languages, elementary electrical engineering and heat engineering in common with other branches of engineering. Instruction in hydraulics, surveying and business law is less favored by chemical engineers than by engineers in other branches of the profession. Some introduction to the problems of management is given a fairly high rating, though recommended by less than a majority and for comparatively few students. A majority favor a preponderantly technical program with business electives and fair sized groups advise supplementary studies in business branches after graduation. The economic aspects of engineering deserve moderately great emphasis, to be given principally in the engineering subjects themselves. Chemical engineers, more than any other group, report a considerable use of modern languages, principally German and French, and recommend their being required in the college curriculum. The tool values of these languages are stressed above the cultural values.

Shop Instruction.—In response to a specific question, a small majority of the chemical engineers, or 55.1 per cent, favor systematic instruction in shop practice. Opinion is fairly equally divided on the question of substituting for shop instruction in colleges a requirement that a definite amount and type of shop experience be obtained during vacation periods, with 40.6 per cent favorable, 37.7 opposed, and 21.7 noncommittal.

Specialization in Chemical Engineering.—Three important questions were considered:

a. "Which of the several divisions of chemical technology and closely allied fields are of such importance as to warrant their inclusion in the training of all chemical engineers?"

In asking this question it was assumed that an adequate grounding in chemical principles and a consideration of fundamental chemical engineering operations such as evaporation, distillation, filtration, subdivision, etc., would be included in all cases. The replies are summarized graphically in Fig.

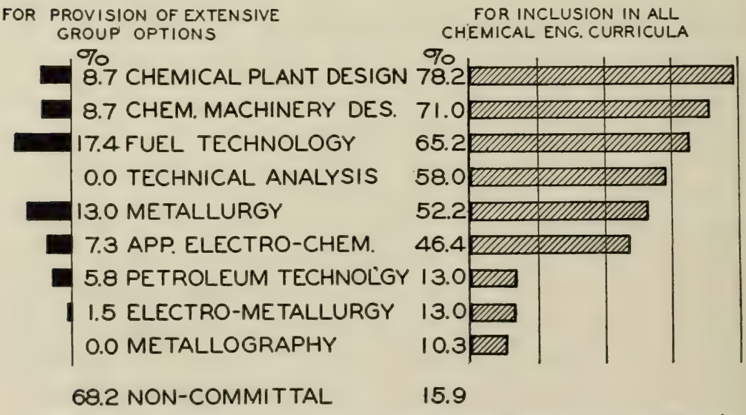

Fig. 16. Divisions of chemical engineering recommended for inclusion in all chemical engineering curricula, or to serve as the basis of extensive group options.

16, and indicate clearly where the line may be drawn between the more general and the more special concerns of chemical engineering.

b. "Should the instruction in the specific chemical engineering subjects aim to prepare men for particular fields of work, such as those listed above, or should they serve primarily as means of teaching fundamental scientific principles and engineering methods of thought and work?"

The verdict on this point is impressive, the latter or more general aim being affirmed by a ratio of twenty-two to one.

c. "Which, if any, of the above divisions of chemical and related technology are of such importance as to warrant the provision of extensive group options in the chemical engineering curriculum?"

The graphical summary of the replies is included in Fig. 16 above.

Considering both the informal comments and the tabulated replies, the verdict is strongly adverse to specialization within the field of chemical engineering for undergraduates. A few favor limited specialization through group options in a few institutions, but the majority would postpone all specialization until after graduation or after college.

Relations with the Organized Profession.—Chemical engineers stand out conspicuously in favoring a more direct influence by the engineering profession, through its national societies, on engineering education and in favoring the formal recognition of colleges which meet approved minimum requirements. No doubt the experience of the A. I. Ch. E. in scrutinizing curricula in chemical engineering and in publishing a list of those approved by its educational committee was a considerable factor in the more positive and favorable expression than that given by other groups of engineers.[7]

General Comments on Engineering Education.—The following examples reflect the temper of the chemical engineering group:

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[7] See Report of Committee on Chemical Engineering Education of the American Institute of Chemical Engineers, 1922.

"Each year I am the more certain that the basic education of chemists, engineers, etc., should be broad, general, liberal, and that the engineering training should follow." (President of firm)

"I doubt if more than one engineering student out of a hundred knows exactly what line of work he will eventually follow. Consequently, the time which is given to specific processes is largely wasted. It seems to me that the first requirement in education is the teaching of straight thinking. Next it is necessary to have sufficient fundamental information, which for the chemical engineer should include a real understanding of mathematics, physics, chemistry and economics. The ability to write well is highly desirable and the ability to read German and French is helpful. If these subjects are covered thoroughly there is not much time left in a four-year course for engineering technology."
(Research director)

"Education, in my opinion, is a question of *habitual* familiarity with ideas, subjects, methods and actual performance, rather than a question of knowledge *about* them. This habitual familiarity can only be acquired through training one's own faculties, not by watching someone else perform or listening to some one else talk about how a third person performed. Most of what we learn about things in college is quickly forgotten. A great deal of it is more or less incorrect anyway. We can find it in books if we need it. If we are any good we can hire some one to stand around and know it for us. But we must aim to compel the student to acquire by practice the faculty of using his own mental tools, his human tools and his mechanical tools with force, precision and dispatch on any material in any direction." (Consulting engineer)

"Education is the foundation on which men are built, and success is not to be measured solely by dollars. Specialized engineering education does not develop men fitted for the emergencies which afford opportunities for advancement, neither is the product well rounded and interested in many things, outside of his specialized business, which were once considered as natural outlets for the spare time of the well educated men. Broad training and a continuance through college years of courses in the humanistics should give the type of man needed in the industries."
(Consulting engineer)

"A consideration would be useful of methods by which we could *separately* educate the artists and the artisans of engineering. I don't know how to make the original choice but I think we all know how to educate the two groups once the choice were made."
(Research director)

"A rigorous and thorough training in fundamentals should characterize the engineering course. Specialization should be reserved for graduate courses. Plant practice should be learned and studied in the field." (General manager)

PART V. CIVIL ENGINEERING

Engineers Consulted.—The civil engineers whose opinions are summarized are college trained men in the ratio of five out of six and represent forty-four American institutions and several in Europe. Seventy per cent were graduated in civil engineering. Classified according to type of connections, the group in private practice is first with 45 per cent, the municipal group second with 13 per cent, the educational group third with 12 per cent, with the groups in federal, railroad and state service, and in manufacturing following in order with less than ten per cent each. Consulting engineers and chief engineers together make up one-third of the group, and men in the higher executive positions one-fifth. The structural branch of practice leads with 23 per cent, the hydraulic branch is second with 15 per cent and the other principal branches are represented by groups ranging from ten to three per cent of those who replied. Taken as a whole, the body of opinion is representative in variety and notable in quality.

Nature and General Content of Curricula.—The opinions of civil engineers included in the graphical tabulations of Part II may be summarized as follows. The program in civil engineering should not be largely differentiated from those of kindred branches of engineering. There should be a broad base of studies in common with other curricula, including mathematics, physics, chemistry, English, drawing, mechanics, mechanics of materials, hydraulics, economics, plane surveying, elementary electrical engineering and business law. A marginal ranking is given by civil engineers to accounting, modern languages and heat power engineering. A majority favor giving some specific instruction in the realm of administration and management, but there is no clear verdict whether this instruction shall be for all students or only for those who desire to elect it. There is no desire to substitute a business emphasis for a dominantly scientific and technical emphasis of the curriculum. Sentiment is about equally divided between offering business electives as a part of the normal undergraduate program and advising special study of supplementary business subjects after graduation.

Civil engineers favor a moderately great emphasis on economics and the economic aspects of engineering, principally through the medium of the engineering subjects themselves. They report both the younger and the more experienced graduates to be less well equipped to deal with the economic problems of engineering than with the technical problems. Nearly seventy per cent of the civil engineers report little or no use of modern foreign languages. German and French are used nearly twice as much as Spanish. A majority hold that the cultural values of modern languages as commonly taught to engineering students are not sufficient to justify the time expended.

By the ratio of five to three the consensus of opinion among civil engineers is that courses in shop practice should not be required of civil engineering students.

Specialization in Civil Engineering.—This subject was dealt with under four questions:

a. "Which of the following specific civil engineering subjects do you consider of such importance as to warrant inclusion in the training of all civil engineers?"

The replies are summarized graphically in Fig. 17. Plane surveying and the structural group stand out strongly, with the sanitary group second and the transport group third among the subjects of primary importance.

b. "Should the instruction in specific civil engineering subjects aim to prepare men for particular fields of work, or should such subjects serve primarily as means of teaching fundamental scientific principles and engineering methods?"

The verdict on this question is emphatic, favoring the latter or more general aim by a ratio of seventeen to one.

c. "Which if any of the divisions of civil engineering are of such importance as to warrant the provision of distinct, complete curricula specializing in these divisions?"

The replies are summarized graphically in Fig. 18. If only

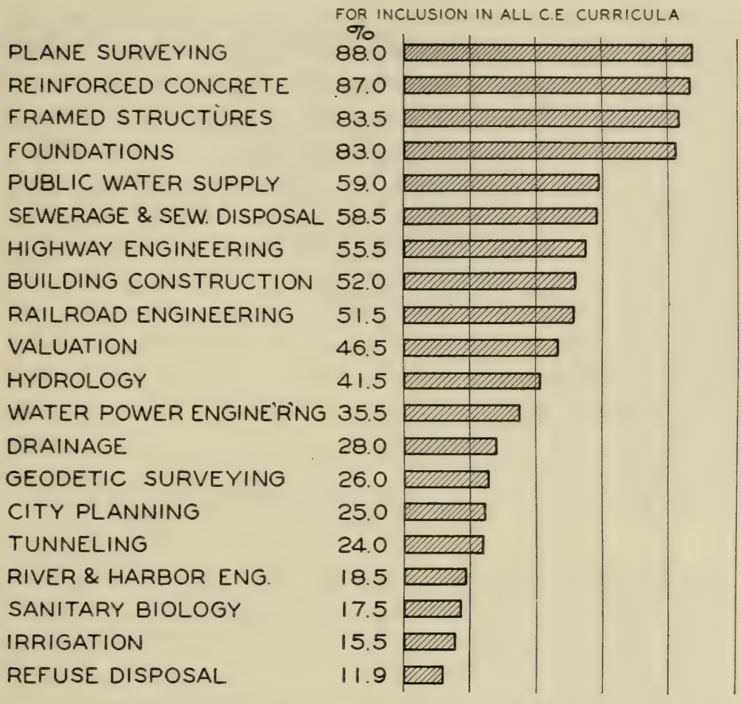

FIG. 17. Civil engineering subjects recommended for inclusion in all civil engineering curricula.

the specific replies to the question are considered, it would seem that considerable support is given to distinct curricula, or at least comprehensive options, in structural, sanitary, hydraulic and railroad engineering. Many of the informal comments which accompany these answers indicate that specific training of this character should be confined largely to post-graduate courses.

d. "If curricula in specialized branches of civil engineering are recommended, should they be established in all, many, or few institutions?"

Nearly two thirds of the specific replies, or 64.3 per cent, recommend *few* institutions; 26.3 per cent recommend *many;* and 9.3 per cent recommend *all.*

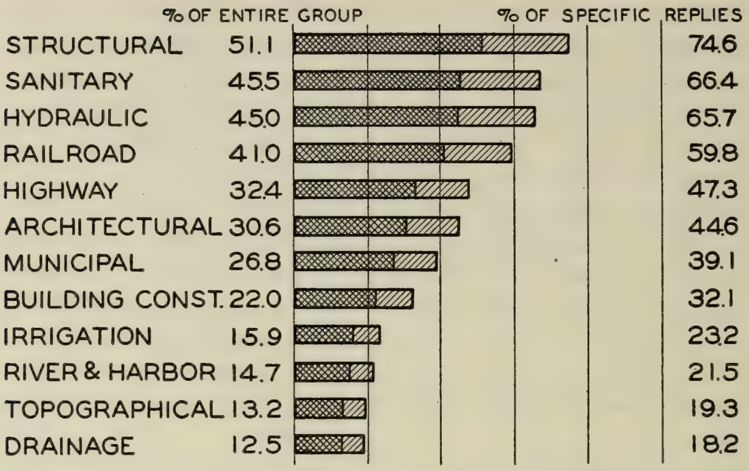

FIG. 18. Divisions of civil engineering for which extensive group options are recommended.

Extent of Instruction in Surveying.—Field work has always occupied a conspicuous place in the training of a civil engineer. As the scope of the profession has broadened in recent years, the amount of time devoted to instruction in surveying has been questioned. The civil engineers were asked to indicate:

"Which of the divisions of surveying should be required of all students of civil engineering and how extensive should the work be in each division?"

A graphical summary of the replies is given in Fig. 19.

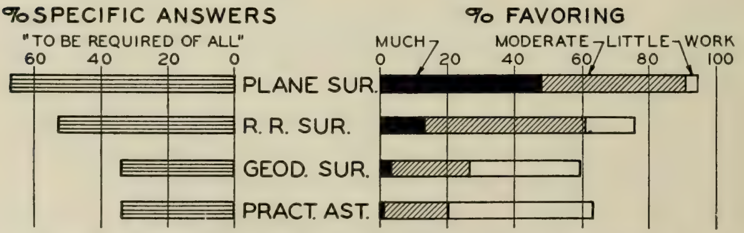

FIG. 19. Recommendations concerning branches of surveying to be required of all civil engineering students and the extent of the work in each branch.

The number who marked the blanks indicating the extent of the work to be given was somewhat greater than the number who indicated which divisions should be required of all. The two sets of replies are consistent in a qualitative sense.

Relations with the Organized Profession.—If only the specific replies are considered, the civil engineers have decisively expressed their desire for a closer bond between the professional body and the colleges and have commended by a considerable margin the proposal to maintain and publish a list of approved institutions.

General Comments by Civil Engineers.—The following comments on engineering education in general are representative of the views of the civil engineering group:

> "There is danger in generalization. Different treatment is needed for various colleges and possibly for same college at different times. Students of different capacities and aims should find suitably different courses of training somewhere among the colleges, but not necessarily with the same college. Between secondary schools and the ultimate terminus of formal education there should be one or more way stations at which men could stop with credit and even honor, or transfer to other lines for completing their schooling. Education cannot be completed in schools, and schools should not try." (Director of foundation)

> "An engineering education assumes that the student is to practice his profession and he must be taught the fundamentals which cannot be learned out of school. He must graduate young enough to take a subordinate position and continue learning and profiting by experience while still young. In this view, the amount he can be taught at school is limited." (Chief engineer, transit)

> "We must get the idea established that we are no longer being called upon to send out finished technicians for a few fields, but are preparing men for entrance to many fields, some new. Broad training in general and thorough preparation in basic subjects is what is needed." (Professor)

> "An engineering education should give the student broad, general knowledge of engineering subjects and related economics. Specialization should be made of one of the major divisions, as Civil or Electrical, but not more finely divided, as Hydraulic or Sanitary. It is rare to have a graduate start practicing on a specialty when he leaves college." (Superintendent of highways)

> "It should aim to train in fundamental principles, and to develop initiative, power and logical thinking. It should not be vocational—as it now generally is—aiming to teach the tricks of some particular job." (Professor, author, consultant)

"I believe in fundamentals for the majority and in training equivalent to that received by Doctors of Medicine for the qualified few. We must train many transitmen and a few chief engineers. It is uneconomical to train too many for chief engineers' positions." (Railroad valuation engineer)

"My observation is that most engineering graduates come out very poorly grounded in the fundamentals of engineering. Sometimes this is the result of robbing the time and the mental concentration which the student should have put on his physics and mathematics by giving him courses on tunneling, irrigation, highway engineering or what not." (Consulting engineer)

"I do not believe engineering schools should all be modelled on one pattern. Schools ranging from trade schools to schools of university rank can each cover a useful field. Those capable of making effective use of broad training should be able to obtain it, but provision should also be made for those less capable or for financial reasons not able to profitably use this broader opportunity." (Consulting engineer)

"Let us have more men who have insight into the economic and social life of people rather than the type of engineering graduate who knows little else than engineering." (General superintendent)

"Students should be encouraged to take an academic course, including literature, languages both modern and dead, political economy, psychology, etc., before beginning an engineering course, as these things are essential to enjoyment and success in life. But they cannot be covered satisfactorily in an engineering course without sacrifice of many fundamental necessities." (Valuation engineer)

"Number of engineering schools should be materially reduced. Number of engineering students should be given short courses, for subordinate positions, and only the most capable men given engineering training of the upper years. Teaching should be supervised and materially improved." (Professor, consultant)

"I consider it hopeless to achieve what might be desired in the way of engineering education if we limit it to a four-year college course, while much might be done towards securing better preparation for entering engineering institutions of learning, much more can be accomplished by encouraging the continuation of engineering education after the regular four-year course." (Rear admiral, U. S. N.)

"I believe that the engineer's horizon should be broadened, his vision cultivated, that he should be trained to see his profession not as a thing apart, an isolated entity, but rather in its proper place in the general scheme of social and industrial evolution." (Engineer, coast and geodetic corps)

PART VI. ELECTRICAL ENGINEERING

Engineers Consulted.—More than nine-tenths of the electrical engineers who sent replies had attended college, with fifty-six American institutions and a number in Europe represented. Approximately seventy per cent of the college men were trained in electrical engineering and twenty per cent in mechanical engineering. In the lines of work represented, manufacturing ranks first, consulting practice second, the power and light utilities third, education fourth, and the communication utilities fifth. Nearly forty per cent of the group are higher executives in industry and more than a quarter are consulting engineers or chief engineers. The group as a whole is largely representative of the leading elements in the profession.

Nature and General Content of Curricula.—The opinions of electrical engineers included in the graphical tabulations of Part II may be summed up as follows. The weight of judgment is strongly against a course of studies which is sharply differentiated from those in other branches of engineering. The broad base of the curriculum, including the matter in common with other curricula, should include mathematics, physics, English, drawing, mechanics, mechanics of materials, heat power engineering, hydraulics, economics, shop practice, and business law. Modern foreign languages, accounting, surveying, industrial management, and psychology are placed in a marginal group. There is little support for specialization within the field of electrical engineering, but a majority of electrical engineers see merit in the functional plan of curricula proposed by their colleague, Professor Bennett, and the ratio of those who would give the plan a trial to those who would not is practically four to one. Doubtless greater familiarity with the idea underlying the functional plan was a factor in this more favorable verdict than that of other groups of engineers, for the plan had been presented in detail in the *Journal* of the A. I. E. E.

Half of the group advise that students of electrical engineering should receive specific training in administration and management, with a minority opposed. Relatively few, however, recommend that this training be given to all students. The majority favor a dominantly technical course of studies with business electives and a somewhat smaller group would make the business studies required. There is a strong sentiment to the effect that economics and the economic aspects of engineering deserve relatively great emphasis, which should be given principally in the engineering subjects themselves. The younger graduates are found to be deficient in their capacity to deal with the economic problems of engineering, but considerable improvement is noted during the first five years of practice.

Shop Instruction.—In response to a specific question, a slight majority consider it desirable to substitute a definite amount and type of shop experience gained during vacations for systematic shop instruction in college. In rating the relative importance of different aspects of shop instruction, the majority (55.7 per cent) stress the technique of shop operations, a somewhat smaller group (39.2 per cent) the economic phases of shop operations, and much smaller groups manual skill (26.5 per cent), and the technique of management (25.1 per cent). In informal comments many emphasize the desirability of combining vacation experience with shop instruction.

Specialization in Electrical Engineering.—This issue was presented through a series of four questions:

a. "Which of the several divisions of electrical engineering are of such importance as to warrant their inclusion in the training of all electrical engineers?"

The replies to this question are summarized graphically in Fig. 20. It was taken for granted that a general foundation course in the principles of electrical and magnetic units, laws, circuits and machines would be required in every case.

b. "Should the instruction in the specific electrical engineering subjects aim to prepare men for particular fields of work, such as those listed above, or should they serve primarily as means of teaching fundamental scientific principles and engineering methods of thought and work?"

As shown in Part II, the latter or broader aim is favored by a ratio of nearly fourteen to one.

c. "Which divisions of electrical engineering are of such importance as to warrant the provision of distinct, complete curricula specializing in these divisions?"

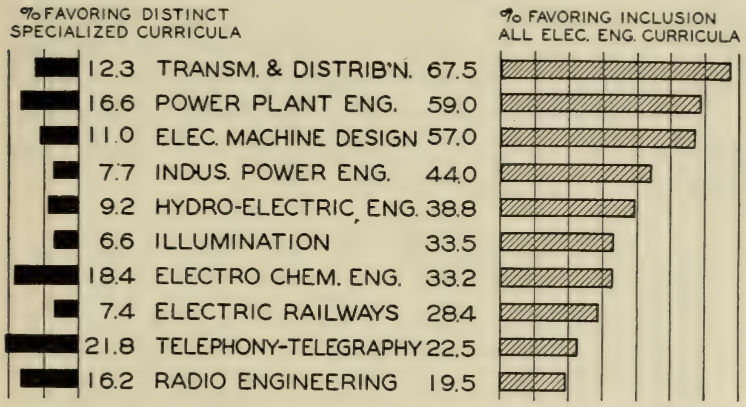

FIG. 20. Recommendations concerning divisions of electrical engineering to be included in all electrical engineering curricula, or to serve as the basis of distinct, specialized curricula.

A graphic tabulation of the replies is included in Fig. 20 above.

d. "If curricula in the specialized branches of electrical engineering are recommended, should they be established in all, many, or few institutions?"

As this was a contingent question only the minority who favor some measure of specialization replied. Of this number, seventy per cent would limit specialization to a few, and twenty per cent to many institutions. About one reply in twelve suggests specialized courses for all institutions; this number, however, is but a little more than four per cent of the entire body of replies. It seems evident that there is very little desire for closer specialization within the field of electrical engineering, before the graduate school or the years of active responsibility are reached. The comments emphasize this position strongly.

Relations with the Professional Body.—While strongly favoring in principle a large influence by the national societies in engineering education, only a minority of the electrical engineers express approval of the proposal to establish and maintain a list of recognized institutions; the number opposed is somewhat less; and a majority indicate that the requirements for graduation and the qualifications of the teaching staff should have the greatest weight if such a list is created.

General Comments by Electrical Engineers.—The following comments indicate the attitude of electrical engineers toward engineering education in general:

"The broader we can make an engineer's training the better, but 'a little knowledge is a dangerous thing.' Better a thorough course in essential fundamentals than a smattering of many subjects." (Engineer, power and light co.)

"Specialization in electrical engineering courses has produced graduates who are technicians and not leaders. The position of chief engineer seems to be the goal. The broadly trained man is fitted to become an executive or to handle broader problems of management and operation. The small number of men who desire to become designers and research men can be prepared better in graduate courses featuring their specialties." (Editor)

"Specialization in his chosen field is necessary, but it should be preceded by general studies applicable to the fundamental principles of business conduct." (Consulting engineer)

"Thorough drilling in fundamentals is far better than teaching a lot of details which one can find in books. The chief feature in education is to teach one how to think and think correctly."
(Consulting engineer)

"Business elements predominate in commercial engineering work. These are best learned through experience. Technical proficiency of graduates is on the wane and yet the fundamental technical knowledge is increasingly necessary. Teaching personnel the major objective to be desired." (Editor)

"I do not favor a standard stereotyped engineering school. We need many kinds, of course all of them good. I believe the public should be better protected against the poor schools, of which there are many, but this must be done without forcing conformation to a specific type." (Professor)

"Education must and does continue after graduation and it seems to me that a very great field for helpfulness exists in the proper direction of this subsequent education."
(Chief engineer, telephone co.)

"Teach a man to demand sound and comprehensive evidence of the facts, give him a thorough understanding of principles, or laws of nature, and then teach him to build carefully on this foundation. Teach him to question, to think, to analyze, to demand an understanding, not to learn by accepting what he is told; that habit is vicious. The subject or field is unimportant—*damn the curricula!*" (Professor)

"I believe we should have two engineering courses:

1. Electro-technicians—4 years.

2. Electrical engineering—4 years in general fundamentals followed by 2 years post-graduate in one of the major divisions of electrical engineering.

3. The degree of E.E. to be conferred only after the full six years' work." (Chief engineer)

"Admission qualifications should require that the applicant has worked at least twelve months in the branch of engineering which he is to take up in school. This would greatly assist the student in choosing his profession, and would enable him to get more benefit from his education." (Consulting engineer)

"If engineering is to maintain its position as a profession and not degenerate into a trade the cultural side of the college career must receive more attention than in the past. An engineer has his life to live as well as being the slave of a machine and his technical ability may be enhanced by a more intimate knowledge of the humanities." (Consultant, industrial relations)

"Engineering education should be an evolution with most institutions evolving by experience in their own way. Stimulus should come from individual leadership, criticism of alumni and the technical world, success of the institution, examples of others, etc. Not by formula or model or outside prescriptions."
(Consulting engineer)

"I believe the student of today has too much of his thinking done for him by others. More effort should be made to develop his initiative and self-reliance." (Design engineer)

"The most important thing is a proper grade of teacher. It is not logical to expect men who would be lined for very low positions in engineering or business enterprises to turn out a product capable of stepping readily into the higher positions."
(Head, research department)

"I am struck that a good engineer may be a very poor teacher. Something should be done to teach professors how to teach, which is an art in itself." (Development engineer)

PART VII. MECHANICAL ENGINEERING

Engineers Consulted.—The list of mechanical engineers contains a larger proportion of men without college training than the other four. The 82.4 per cent who report college training represent fifty-one American institutions and a number abroad. Four-fifths of the college men have taken the course in mechanical engineering. The largest group, classed by type of connections, are in manufacturing with forty per cent of the whole number; fifteen per cent are in consulting service and seven per cent in public utilities. Half of the entire number, or sixty per cent of those stating their responsibilities, are industrial executives of high rank. Relatively few educators were included in the list canvassed.

Nature and Content of Mechanical Engineering Curricula.—The opinions of mechanical engineers included in the graphic tabulations of Part II may be summarized as follows. There is a marked preference for a broad general course of studies rather than one which is sharply differentiated from other branches of engineering. The foundation studies in common with other curricula should include mathematics, physics, chemistry, English, mechanics, mechanics of materials, elementary electrical engineering, thermodynamics, shop practice, economics, business law and industrial management, with accounting, industrial relations and modern languages given a marginal rating. There is a recognition of merit in the functional scheme of curricula by a moderate margin and a somewhat greater degree of approval for a trial of the plan, but the balance of opinion remains in the hands of the noncommittal group. The comment on the functional scheme is principally adverse, stressing the inability of the boy to choose or of the school to classify, and opposing the plan as a form of specialization. There is a strong preponderance of favor for a moderate to great emphasis on economics and the economic aspects of engineering. More than two-thirds of the expressed opinions call for more economic emphasis in the engineering subjects themselves. By a decisive ratio of four to one, it is stated that engineering graduates are not now as well qualified to deal with the economic aspects as with the technical aspects of engineering problems. Comments on the teaching of economics uniformly call for a closer linking of the subject with engineering.

Specialization in Mechanical Engineering.—Four of the questions asked fall under this head:

a. "Should the purpose of the specialized mechanical engineering subjects be to prepare men for particular fields of *work, or should they serve essentially as media for the teaching of fundamental scientific principles and engineering methods?"*

Preference for the broader purpose predominates by the ratio of five and a half to one.

b. *"Which of the several divisions of mechanical engineering do you consider of such importance as to warrant their inclusion in the training of all mechanical engineers?"*

The opinions are summarized in Fig. 21. The primacy of machine design is fairly striking. This branch with the two branches of heat power, make up the backbone of the distinctive training in mechanical engineering in the judgment of these engineers.

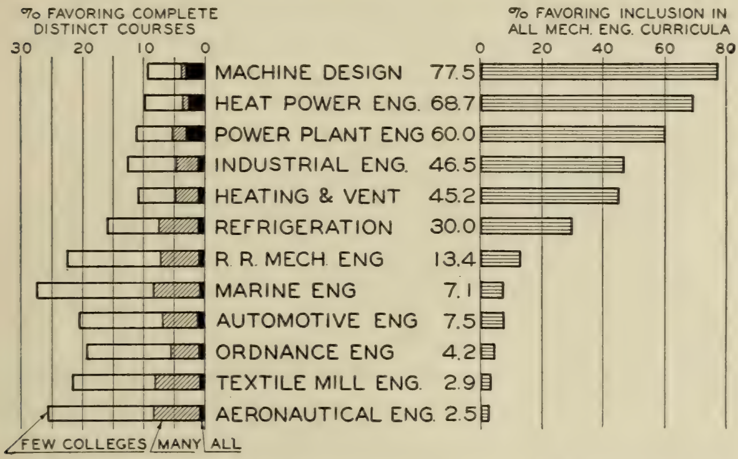

FIG. 21. Recommendations concerning branches of mechanical engineering to be included in all mechanical engineering curricula, or to serve as the basis of complete, distinct courses.

c. *"Which, if any, of the above divisions of mechanical engineering are of such importance as to warrant provision for distinct, complete courses, such as courses in Automotive Engineering or Marine Engineering? Should these courses be given in all, many or few institutions?"*

The replies are summarized graphically in Fig. 21. There is little demand or support for specialization in the divisions of mechanical engineering among this group of engineers, and it is plainly their desire that few institutions should carry specialization to the extent indicated by the question. Many would limit all specialization of this order to post-graduate courses. An engineer of the Bureau of Mines puts the case for limited specialization succinctly in the words: "A specialized course in anything should be available somewhere."

d. "In general, do you feel that the needs of industry and the profession would be better served by a relatively small number of courses in the major divisions of engineering, or by a rather considerable number of special courses from which a student could choose, and which would be designed to fit men for particular divisions of work?"

The verdict in favor of a small number of courses in major divisions is decisive, the ratio being five to one.

Training in Management for Mechanical Engineers.—The opinions expressed under this head deserve special consideration, first because of the large number of prominent industrial executives in the group canvassed, and second because the division of mechanical engineering is likely to be the heaviest loser in enrollment and prestige when a distinct division and curriculum in Engineering Administration or Industrial Engineering is established. The question was stated as follows:

"Do you think that the best preparation for this type of work is through sound courses in mechanical engineering with some attention to administration and management (possibly in the form of a subject of instruction given in the junior or senior year), or through special courses variously designated 'Engineering Administration,' 'Industrial Engineering,' and the like?"

In reply, seventy per cent express a preference for "sound courses in mechanical engineering," fifteen per cent for special courses emphasizing administration and management, and fifteen per cent are non-committal. The informal comments elicited are particularly striking. A number voice emphatic disapproval of the special courses referred to:

> "There is so much humbug in this that I hesitate to answer."
> (Consulting engineer)

> "This generalized administration or executive engineering fad is being over done. Much of the Industrial Engineering of today is bunk." (President, manufacturing co.)

> "It is folly to suppose that green students can profitably spend time on management when they have had no experience."
> (District manager, tool manufacturing co.)

> "Special courses in management often mistake the mechanics of management for the principles and the graduates of such courses have too much to unlearn." (Superintendent)

> "It has always seemed to me that the courses in Administration and Industrial Engineering are refuges for the incapable."
> (Power plant engineer)

The other side of the issue has its strong upholders, however:

> "The coming basic engineering course, I believe, will be a development from existing courses designated as Management Engineering, Industrial Engineering and the like. Therefore I believe instruction of this kind should be given to every engineering student." (Editor, management journal)

> "All engineers should be taught the principles of management, even if some of the other courses have to be sacrificed."
> (President, manufacturing co.)

The following statement is representative of the median opinion:

> "A relatively brief time, devoted mainly to lectures by mature experts who are enthusiastic and broad in methods, will be sufficient. This calls for the highest grade of teaching."
> (Consulting engineer, lead co.)

Instruction in Shop Practice.—In view of the diversity of opinion in teaching circles as to the scope and purposes of shop instruction, the following questions were asked of the mechanical engineers:

a. "What, in your opinion, should be the primary purpose or purposes of such courses—training in manual operations and acquirement of skill therein, training in management and production methods, training in the economics and business aspects of shop work, etc.?"

The replies are summarized in Fig. 22.

b. "In your opinion would it be desirable to require students to acquire shop experience through vacation employment, provided, of course, that practical plans could be devised, or is it desirable to give some shop training in college?"

The replies are shown graphically in Fig. 22.

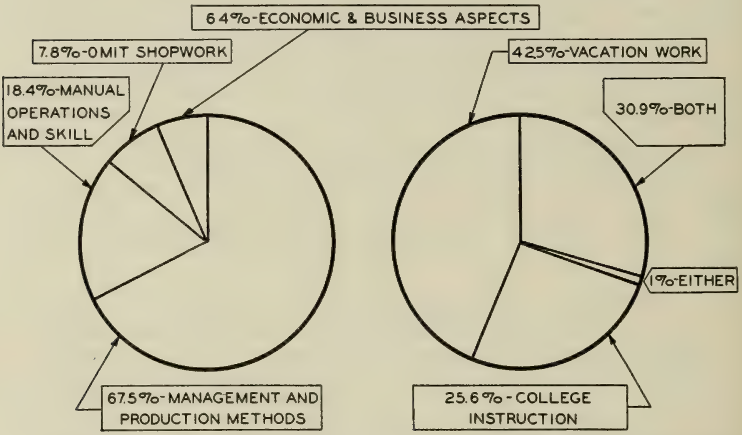

FIG. 22. Methods of training in shop practice (right) and aspects to be emphasized in college instruction (left), recommended by mechanical engineers.

The comment on these questions emphasizes the fact that the college is better organized to do systematic teaching, but that real knowledge of men and methods can be had only through industrial experience. It would seem, however, that mechanical engineers are disposed to give this type of instruction less emphasis than hitherto, and favor more emphasis on the laboratory aspects than on manual training. Many express the view that the latter properly belongs to the high school period and to vacation experience.

Influence of the Organized Profession in Education.—The mechanical engineers stand first among the five groups in the proportions of replies which definitely favor and definitely oppose a more direct influence in engineering education by the national societies. In approving the proposal to set up a list of approved institutions they rank second to the chemical engineers in favoring the plan and show a smaller degree of definite opposition than the other groups.

General Comments on Engineering Education.—The following have been selected as indicating the range and trend of opinion among mechanical engineers:

> "I believe the society can do much through a careful study of the answers to this questionnaire to improve the character of the courses offered in the schools of the country."
> (Vice-president, utility co.)

> "I believe the A. S. M. E. and other engineering societies should advocate a much more adequate teaching of the sciences not only in the general college courses (non-engineering) but also in the schools down to even the lower school grades. The ignorance of our average citizen as to the great modern developments in science and his ignorance of natural laws is startlingly at variance with the great strides which have been made in scientific knowledge; and the methods of teaching science and the little time devoted to it in the schools does not promise much improvement until present methods are radically revised." (Vice-president, ship building co.)

> "In some way, if possible, the students who are to be favored with an engineering education should in advance have shown a natural talent or adaptability for such careers. The present haphazard way in which students take up engineering is a waste of time and money and results in many misfits."
> (Member, engineering firm)

> "The best training for a man with engineering tendency is an academic (so called) course followed by an engineering course. My general feeling is that the engineer should aspire to the management and control of industry and that his scheme of education should recognize this as a possibility and provide for it in his preparation for the profession." (Manufacturer)

> "In Germany, specialization often centers about outstanding teachers or equipment. I think the time is ripe for five-year courses with specialization in the fifth year." (Research engineer)

> "In general I believe (*a*) The student engineer should receive more cultural and inspirational training; (*b*) should specialize only in graduate work; (*c*) should spend more time in part time work in the industries." (Consulting engineer)

> "I believe engineering education should be exceedingly thorough in the studies taken and in no sense a smattering. Many of the men who come to my office are not well prepared in any line, and have a smattering of so many subjects that they do not know any one well enough to use as a starter to build on." (Chief engineer)

> "Successful engineering education depends primarily on advice with general supervision under the collective engineering judgment to be found in our national engineering societies."
> (Assistant to president, manufacturing co.)

"I believe that quality in training is due more to character of instructing staff than to anything else. Men will grow men. Better teachers will produce better graduates and the curriculum should not be the dominating factor." (Vice-president, manufacturing co.)

"Engineering education should be linked up with engineering practice. College professors should devote some time to actual practice." (Superintendent)

"Would hope that a son of mine would spend a year between sophomore and junior years at work in industry to be able to appreciate 'what it's all about anyway' in the junior and senior years." (Plant engineer)

"It is well to bear in mind that the world's work is done by the mediocre, and it is he whom we have to take care of in educational matters. The genius will take care of himself."
(Mechanical engineer, manufacturing co.)

PART VIII. MINERAL TECHNOLOGY

Scope of Inquiry.—The division of education commonly designated by the collective term ''mining engineering'' is actually a group of programs devoted to fairly distinct technical divisions of the mineral and metal industries, to which the term ''mineral technology'' is here applied. The breadth of the field, the large number of institutions offering training and the relatively small total enrollment of students give rise to peculiar educational problems which are reflected to some extent in the questionnaire.

Engineers Consulted.—Thirty-two fairly distinct fields of work are represented among the 177 engineers who answered the questionnaire. All but four received college training. Forty-five American institutions are represented, as well as a number in Europe. Sixteen types of college preparation are indicated, the group trained in mining engineering being in the lead with 38.8 per cent, with none of the other groups reaching eight per cent. Among the types of position held by the respondents, the industrial executives predominate with 39.4 per cent, consulting and chief engineers total 18.5 per cent, educators 10.5 per cent, geologists 7.9 per cent, and the remainder are engineers and metallurgists of various classifications. The leading elements in all branches and types of mineral technology are represented with the exception of ceramics and cement and glass technology.

Nature of Curricula in Mineral Technology.—The verdict of the group is consistently in favor of broad training, given in curricula which are only moderately differentiated from those in other branches of engineering. The group were asked to indicate a preference from four general plans of specialization as follows:

1. "*A single inclusive curriculum concerned only with the fundamental principles and methods of engineering as an introduction to mineral technology, to be followed by specialization in practice or in post-graduate study.*"
2. "*A single basic curriculum for three years, followed by a group of options in such branches as metal mining, coal mining, metallurgy, petroleum technology, mining geology, and ceramics in a final year.*"
3. "*A group of fairly distinct, complete curricula in the several branches of mineral technology.*"
4. "*The first plan for the majority of institutions and plan number—for a few of the largest and most favorably situated institutions.*"

The preferences indicated are shown graphically in Fig. 23.

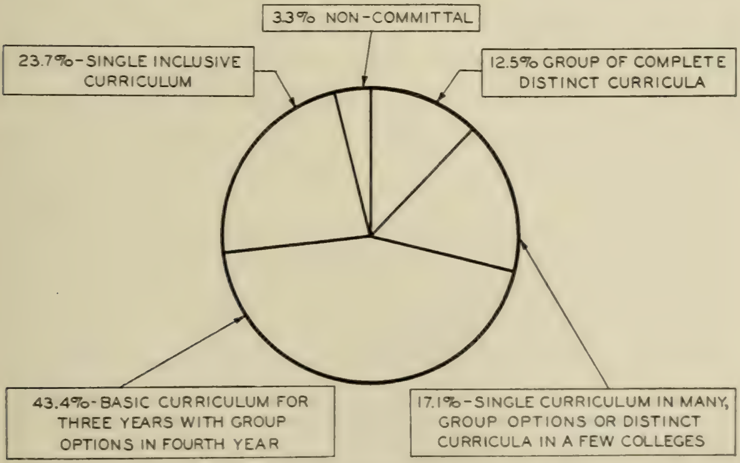

FIG. 23. Preferences of mining engineers as to the general plan of curricula in mineral technology.

Those who favor some division of the curriculum, as suggested in the second and third plans stated above, were asked to indicate what subdivisions should be provided for and their choices are shown graphically in Fig. 24, both as percentages of the entire group and of the group who answered the specific question.

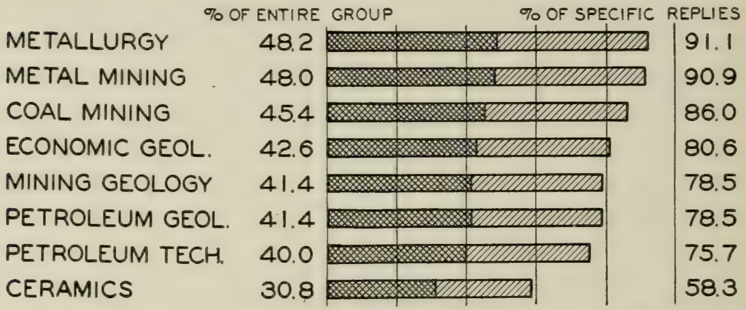

Fig. 24. Group options in divisions of mineral technology recommended by mining engineers.

By a ratio of three to one, the majority hold that the instruction in specific technical subjects should serve primarily to teach fundamental scientific principles and engineering methods of thought and work, rather than to prepare men for particular fields of work. The comments appended to the answers to these questions almost unanimously support the ideal of broad training, subject to care not to make the technical courses so general that they become superficial.

Content of Curricula.—The base of general content in mining curricula may be inferred from the subjects which this group recommend for inclusion in all engineering curricula. These include mathematics, physics, chemistry, English, drawing, mechanics, elementary electrical engineering, economics, surveying, hydraulics, mechanics of materials, geology, and the chemistry and metallurgy of engineering materials. Modern languages, business law, accounting, heat power engineering, and management are given a marginal rating.

A moderate majority express the opinion that students of mining engineering should receive specific training in the realm of administration and management, and a considerable percentage would provide such training for all mining students. The plan most favored is that of a preponderantly technical course with electives in business subjects; a considerable number, however, would postpone this training until after graduation. In the wide range of opinions expressed through comments, the following may be taken as representative of the median and dominating position:

> "While many will never become administrators, it is important that all should be able to orient themselves to their organizational environment by understanding its nature."
>
> (Engineer, Bureau of Mines)

Both the formal and informal opinions of the mining group invest the economic aspects of engineering with great importance in the curriculum and subject matter. With few exceptions these engineers have not found the younger graduates well qualified to deal with the economic problems of engineering; they note considerable improvement among graduates of five years or more of experience, but still regard them as deficient on the economic side. Seventy per cent of those who suggest means of giving the proper economic content and emphasis favor greater emphasis on the economic aspects of the engineering subjects themselves; about one-fourth would seek a remedy through courses given by the department of general economics and an equal number through courses given by a special division concerned with the economics of engineering.

The use of modern foreign languages by mining engineers and their estimate of their value in the curriculum are particularly significant in view of the large amount of mining activity carried on in foreign countries. Nearly sixty per cent of the respondents indicate much or moderate use of foreign languages, with German, French, and Spanish used in fairly equal degrees. It is the majority opinion that modern foreign languages as generally taught to engineering students are not justified by their cultural value in proportion to the time expended. The comments indicate that mining engi-

TABLE II

SUBJECTS RECOMMENDED FOR INCLUSION IN CURRICULA IN MINERAL TECHNOLOGY

(The results are expressed by the percentage of the whole number of specific replies which recommend the subject either for all curricula or for one or more curricula in the technical branches.)

	All Curricula	Mining	Metallurgy	Economic Geology	Petroleum Technology	Ceramics
Physical and Historical Geology	77.2	44.9	26.6	47.4	38.2	29.1
Field Geology	39.0	53.9	14.9	64.0	50.0	27.5
Geological Surveying	19.4	58.2	5.0	73.2	54.4	16.8
Economic Geology	55.0	56.6	21.8	57.5	42.4	27.4
Mineralogy	74.7	56.7	40.8	50.6	36.6	33.3
Petrography	40.8	44.9	25.8	61.5	33.3	24.9
Oil and Gas Geology	5.8	13.3	1.7	55.7	79.7	1.2
Petroleum Production	1.7	4.2	3.3	25.8	82.2	0.0
Petroleum Refining	0.8	0.8	3.3	5.8	78.0	0.0
Gas Engineering	5.8	8.3	39.8	5.0	74.8	18.2
Mine Surveying and Mapping	30.7	80.3	9.1	39.1	13.3	11.8
Mine Drawing	17.5	82.2	7.5	26.6	7.5	10.0
Mine Layout	11.7	86.5	5.0	12.6	2.5	7.5
Mine Structures and Timbering	10.0	86.5	3.3	7.5	0.0	3.3
Mining Machinery	13.3	84.1	7.5	6.6	0.8	4.1
Excavation, Boring and Tunnelling	17.7	84.9	3.3	17.5	15.8	8.3
Mine Ventilation and Drainage	10.8	87.5	1.6	3.3	2.5	4.1
Hoisting and Transportation	12.5	85.0	9.2	7.5	2.5	10.0
Metal Mining Methods	18.3	82.4	26.2	25.0	3.3	9.2
Coal Mining Methods	13.3	75.0	10.0	20.8	7.5	10.0
Mine Valuation	25.0	77.5	11.1	37.5	10.0	12.0
Mine Management	24.2	75.0	6.7	15.9	10.0	8.3
Mining Law	29.1	72.1	12.3	30.0	14.9	6.6
Sampling and Assaying	40.0	71.6	56.6	40.7	8.3	20.0
Ore and Coal Dressing	15.8	69.0	58.2	18.2	4.1	8.3
Metallurgy of Iron and Steel	28.3	27.5	82.2	8.3	5.8	5.8
Non-ferrous Metallurgy	19.1	28.3	79.8	10.0	3.3	14.2
Physical Metallurgy	12.3	15.8	81.6	5.8	1.6	6.6
Metallography	5.8	12.3	83.0	16.6	1.6	5.0
Metallurgical Calculations	12.3	20.0	83.0	4.2	4.1	12.3
Metallurgical Plant Design	5.0	11.8	86.0	4.1	3.3	13.3
Industrial Furnaces and Refractories	7.5	5.0	73.0	2.5	11.8	45.0
Pyrometry	7.5	6.8	79.0	5.0	11.8	45.0
Coking and By-Product Distillation	4.2	14.0	60.7	7.5	25.8	11.2
Properties and Preparation of Ceramic Materials	7.5	3.3	18.2	16.6	6.6	63.3
Ceramic Processes	0.8	0.0	6.8	4.2	0.0	69.0
Ceramic Calculations	0.0	0.8	2.5	4.1	0.0	70.8
Ceramic Design	0.0	0.0	1.6	3.3	0.0	69.6
Cement Technology	5.0	7.5	11.0	8.3	3.3	66.4
Glass Technology	1.7	0.8	6.6	6.6	0.8	74.8

neers, more than other groups, place the primary value upon ability to speak, rather than to read, foreign languages.

Technical Content of Curricula in Mineral Technology.— The range of technical subject matter in the broad field of mineral technology is so wide that selection is imperative. Engineers were asked to designate the subjects which are of such general importance as to warrant their *inclusion in all curricula in all branches* of mineral technology and those which should be *included in the curricula of the special branches* related to mining, metallurgy, economic geology, petroleum technology, and ceramics. The results are summarized in Table II.

The variety of the subjects of study included in the table is eloquent testimony to the difficulty of effectively organizing a system of training for the comprehensive field of mineral technology with an enrollment of students rather thinly distributed over a large group of institutions. The comparatively small number of subjects recommended for all of the technical branches in common emphasizes the difficulty in meeting the situation through a single basic curriculum extending through the entire undergraduate period. Outside of a few broad fundamentals a single curriculum would tend to become a compromise between rather slightly related elements, with the danger of being diffuse and superficial. From the fairly distinct nature of the group combinations advised under the several technical branches, it would seem that at least one year of differentiation within the field of mineral technology is fairly imperative, with separate group options in mining, metallurgy, petroleum technology, and economic geology. Ceramics has relatively few common elements and appears to merit a specialized curriculum in a few institutions where it can be adequately cultivated. Salvation for education in mineral technology appears to lie along the line of a considerable specialization by institutions, with a moderate number giving fairly general work in metal mining and metallurgy, and with relatively few emphasizing the other branches of the industry.

Influence of the Profession on Engineering Education.—The mining engineers, by a small majority, favor a larger influence on education by the national societies. There is little dissent, however, though many remain non-committal. The proposal to create a list of approved institutions brings a sharper alignment; the ratio of approval to opposition is practically five to four, or the lowest among the five groups.

General Comments by Mining Engineers.—The following have been selected as representative:

> "The two important factors in education are first the boy, and second the teacher. The subjects themselves are secondary. A great teacher of the classics operating on the right kind of boy could produce a good mining engineer. We tend to overemphasize the subjects taught, as compared with the men who teach them, and the boy who is being taught.—The right boy can sometimes do wonders with very poor instruction and instructors, and a great teacher can sometimes do wonders with indifferent students."
> (Superintendent and chief engineer)

> "The members of our technical societies are best qualified to guide and foster our technical education along the right channels. The result of present educational methods and standards is far from satisfactory. Why is it necessary for our engineers of today to begin their life work by trying to 'forget all they ever learned in college?' " (Chief engineer, zinc co.)

> "While the tendency today in engineering practise is toward specialization and while this must inevitably increase, I believe that the educational period of an engineer's life should be as broadly general as possible within the limits of a reasonable specialization, such as mining, electricity, chemistry, civil and mechanical engineering." (Consulting engineer)

> "A group of students resembles a miscellaneous collection of larvae, 10% of butterflies and 10% of beetles. Each of the latter is destined to bore a hole into a nut and to feed there until he dies, but the former become engineering butterflies. For whom then is the education designed? The butterflies or the beetles?"
> (Engineer, Bureau of Mines)

> "The economic value of engineering should be stressed at every turn. The engineer must know more about business in order to protect his own interests and help sell his services at a fair price,—which the majority are not doing now." (Mining engineer)

> "The basis for success in higher education is to be found in better primary education. The colleges cannot graduate city men for the coal mines. They must take the men from the coal mining field and these are hampered by the poor schools and poor teachers in the coal mining communities." (Editor)

> "This is called Specialist's Age. Most engineering graduates know too little about too much and have not had the power to think drilled into them. There is too wide a difference in men from dif-

ferent schools. In general the small technical school men take hold with better intelligence." (Superintendent and metallurgist)

"Deem it advisable to thoroughly train in the fundamentals. Business knowledge and judgment are gained from active experience under 'fire.' Cannot make a finished technologist in college atmosphere. Harmful when tried as student gets a wrong perspective of himself in relation to actual industrial pursuits." (Vice-president and consultant)

"(*a*) A rigorous and thorough training in fundamentals should characterize the engineering course. (*b*) Specialization should be reserved for graduate courses. (*c*) Plant practice should be studied in the field." (General manager)

"I am convinced that the engineering profession should exercise a much more direct influence on engineering education. I am inclined to think that a national body should be formed for this particular purpose, with members to be elected by the several national societies." (Vice-president and general manager)

"In brief, my criticism was: too great detail in some branches, and too little general education; too much mathematical grind, too little of the humanities; too little economic geology from the broader point of view, too much intricate differentiation of rock technicalities; too little on the side of business management, personnel and economics; too sharp specialization before students are prepared to receive it or to know what it all means." (Consulting mining engineer)

"Two of the more important basically wrong factors which are quite obvious are the facts that our output of 'engineers' is at once much too large and of very indifferent quality and second that the returns, financial and otherwise, from teaching are not such as to attract some who would be most valuable in such capacity." (Consulting engineer)

"If the instructors in our schools can be made to see that teaching is their most important function and be induced to claim and give each other credit for success in teaching, the whole subject will be much simplified. A very large proportion of our instructors apparently believe that only research work should be considered. Fundamental research work is of the greatest value and importance but very few men are capable of doing it and still fewer are capable of teaching at the same time. Much of the so-called research work is trying to devise new processes by men who do not know fundamental economic conditions by which they can be judged." (Editor)

BULLETIN NUMBER 15
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A STUDY OF PLACEMENT EXAMINATIONS

by

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Promotion of Engineering Education
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A STUDY OF PLACEMENT EXAMINATIONS

By

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Purposes. The study described in this bulletin was intended to test the usefulness of the Iowa Placement Examinations in engineering colleges. These examinations constitute a series of educational tests designed to measure the training and aptitude of students for subjects commonly included in the first year of engineering curricula. A more complete description of the examinations will be found in the following pages. The trial of the examinations was made by a group of engineering colleges and other institutions in the years 1924–25 and 1925–26. Almost all of the material which follows is based upon the results of that trial. An exhaustive discussion of the various types of special examinations, intelligence tests, and other kinds of educational measurements that have been developed in the past few years will not be attempted, nor will the more technical aspects of the preparation and analysis of such tests be dealt with.* Since, however, placement examinations are designed to serve the purpose, among others, of sectioning classes on the basis of ability, a brief discussion of that procedure will be included.

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* A more extended technical discussion of the examinations will be found in ''Iowa Placement Examinations,'' by George Dinsmore Stoddard; Volume III, Number 2, of *Studies in Education,* issued by the State University of Iowa.

Auspices. The Iowa Placement Examinations were constructed by Dr. George D. Stoddard under the general direction of Dean C. E. Seashore of the Graduate College of the State University of Iowa and Professor G. M. Ruch of the College of Education of that institution. Assistance in preparing the examinations was given by members of the faculties of the several departments of instruction to which the examinations relate. The Society for the Promotion of Engineering Education, under whose auspices the present study was conducted, through the Staff of its investigation of engineering education, cooperated in having the examinations given to students and assisted in securing their scores in the examinations and grades in corresponding subjects of the freshman year.

Colleges Participating in the Study. The institutions which participated in the trial of the examinations furnish a representative sampling of the engineering colleges of the country. Five are polytechnic institutes and schools of mines offering engineering courses only, three are privately endowed arts colleges and universities, six are land-grant colleges, twelve are state universities, and one is a municipal university. Twenty-three other institutions which do not offer engineering courses also participated, but the number of their students who took the examinations was relatively small, more than two-thirds of all the students reported upon being definitely enrolled in engineering courses. The institutions are quite well distributed in the various parts of the country, there being some preponderance of institutions in the Middle West. All of the institutions represented in the study admit primarily by the certificate plan.

The number of cases reported upon was amply large to warrant the conclusions drawn on the following pages. The numbers of students taking the various examinations ranged from over eight thousand in the English Aptitude Test to about one thousand three hundred in the Physics Training Test. The numbers of students whose first semester grades were reported was smaller but was ample for any desired analysis and discussion of the results, the number in mathematics, for example, being over one thousand. In many instances results reported in this bulletin are based upon a sampling of cases drawn from the whole number, but in no case is an inference drawn or a result reported concerning which there is any important statistical doubt.

Relationship of Placement Examinations to Other Kinds of Special Tests. In the past few years, and particularly since the war, the science of educational measurement and the use of special kinds of tests, such as so-called tests of general intelligence, have made rapid progress in higher education. Such measurements and tests have probably been applied to a less extent in divisions of education which prepare for the professions than they have in general collegiate courses. They have, nevertheless, been applied to some extent in engineering education. Great impetus was given to the whole science of educational measurement through the use of the Army Alpha Test in the American army during the war. In engineering education, the report of Dr. Charles R. Mann * in which he discusses the special tests of engineering aptitude constructed by Professor E. L. Thorndike had considerable effect in promoting the use of special tests of various kinds. In fact Dr. Mann's report led directly to a trial of special forms of examinations by a considerable number of engineering colleges pursuant to the following resolution passed by the Society at its annual meeting in 1919:

> ". . . That this society through its Committee on Admission, or otherwise, recommends that as a matter of experiment and research, psychological, 'objective,' 'trade,' or other similar tests be given to all students after admission to engineering courses of study and that the ratings thus obtained be compared with their subsequent scholastic progress."

In accordance with that resolution six tests were prepared under the direction of Professor L. L. Thurstone and a special committee of the Society and were administered to over seven thousand students at the time of their admission to engineering colleges. Discussions of the results will be found in the publications of the Society for the years 1920, 1921 and 1923. This experiment may be regarded as a part of the general movement in higher education toward objective valuation of student abilities and performances. It had as its purpose the measurement of general aptitude for the study of engineering. In its immediate purpose the experiment differed from the trial of the placement examinations, as will appear later.

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* *A Study of Engineering Education*, by Charles Riborg Mann; Bulletin Number Eleven of the Carnegie Foundation for the Advancement of Teaching.

Function of Placement Examinations. The general purpose of the kinds of tests to which reference has been made is the measurement of scholastic aptitude as a means of predicting probability of success in courses of study extending beyond the point to which the student has advanced. The placement examinations are designed to serve that purpose more specifically by measuring the aptitude and the preparation for particular subjects of the curriculum. At the same time the composite score of the entire series of examinations, or any considerable part of the series, serves as a general measure of scholastic aptitude. Each of the examinations comprising the series relates to one of the subjects commonly prescribed for the work of the freshman year of engineering colleges. The purposes of the examinations are best summarized in the following words of Dean C. E. Seashore:

> (1) It will be devoted to a single subject or field of knowledge such as English, mathematics or chemistry;
>
> (2) It will differentiate between training in a subject and natural aptitude or fitness for that field of work;
>
> (3) It will be a departmental affair and will be given separately by each department in its immediate interests and needs;
>
> (4) It will serve as an introduction to the subject, being prepared partly with the purpose of reminding the student of the essential prerequisites for the course and indicating the general character of the activity that will be pursued in the course, and being so written from the point of view of the art of teaching that it shall constitute the most profitable exercise for the first two hours of the course;

(5) This examination should give, at the end of two hours, as adequate information about the student's place and needs in the course as the instructor ordinarily acquires by the end of the first semester under the traditional methods of instruction;

(6) The record of a general intelligence test may be used to supplement this examination, but that is not essential, as a series of placement tests will be more significant than a general intelligence test;

(7) It will be prepared by or in responsible collaboration with a successful teacher and writer in the specific subject;

(8) It will be given for a specific purpose and the results will be applied immediately in the organization of sections of the class on the basis of this objective information about the character of the preparation and the natural aptitude for the subject.

The results of the examination in accomplishing these purposes will be discussed later.

Placement examinations have not as yet been used as a definite requirement for admission to college—nor, with a few exceptions, have other similar tests—though they have been employed as parts of general admission procedures. If desired, they may, however, be used as a basis for the selection and admission of students either as a definite requirement or as a means of giving advice as to the probability of success or failure.

Placement examinations also furnish information to teachers and educational advisers whose duty it is to deal with individual students and to render advice and assistance to those in scholastic difficulty and to those of superior ability who merely do enough work to pass the formal requirements of their courses.

Description of the Examinations.* Each examination deals with a particular subject commonly included in curricula of the freshman year and is divided into two parts: one a test of aptitude and the other a test of training.

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* Sample copies of the examinations may be obtained from the Bureau of Educational Research and Service, The State University of Iowa, Iowa City.

The aptitude test is a special type of intelligence test designed to measure those skills and abilities which bear particularly upon the subject in question. It is designed, in so far as possible, to measure specific aptitude for that subject rather than scholastic aptitude in general, and to measure these qualities irrespective of the training which the student has had in the subject in question in the secondary school. The aptitude test is not entirely, as its name may imply, a test of innate or native abilities, nor is it intended to eliminate completely the measurement of scholastic preparation, but it is intended to measure those portions of the student's ''preparation''—scholastic and otherwise—which while not given in school in the particular field of the subject do nevertheless have a bearing upon the probability of success in it. The Chemistry Aptitude Test, for example, is designed to measure ability to make simple arithmetic and algebraic computations, to measure reading comprehension, *i.e.,* the ability to comprehend and interpret written statements of various degrees of difficulty and complexity, and to determine the student's interest in chemistry from the extent and the accuracy of such information concerning chemistry as any intelligent youth might have acquired from popular reading or in other ways in daily life. These measurements do not determine the extent or quality of the student's preparation in the specific field of chemistry as acquired in the secondary school but they do measure certain factors which have an important bearing upon subsequent scholastic success in that field.

The Chemistry Training Test is designed to measure accurately and objectively how much knowledge of the subject has been retained by the student. The chemistry test, for example, measures knowledge of fundamentals of chemical processes; determines the extent and accuracy of the student's knowledge of valencies, formulas, names of compounds and the use of chemical formulas; tests ability to solve chemical problems; and examines the student on his knowledge of chemical manufacturing processes.

The ''objective'' type of question is employed throughout the tests. Certain questions are of the *true-false* type consisting of a statement, the correctness or incorrectness of which the student is required to indicate. Others are of the *completion* type wherein certain words or phrases are omitted which the student is required to supply. The so-called *multiple-response* type in which several alternative answers are supplied and the student is required to choose the correct one is also employed. Certain of the questions are of the *recall* type which is similar to the usual examination question but is answered by supplying merely a figure, a word or a short phrase.

Two editions of the examinations have been published, a trial edition in the fall of 1924 and a revised edition in the fall of 1925. The revised edition was prepared after the experimental trial of the first edition and embodies such modifications as appeared desirable in the light of the results of the trial series. The complete set of examinations now consists of the following parts:

Chemistry, Training and Aptitude,
English, Training and Aptitude,
Foreign Language Aptitude,
French Training,
Spanish Training,
Mathematics, Training and Aptitude,
Physics, Training and Aptitude.

A brief description of the Chemistry Aptitude and Chemistry Training examinations is given below as an illustration of the subject matter covered in the tests. A complete summary of the same kind covering all the examinations is given in the Appendix beginning on page 39.

Chemistry Aptitude, CA–1 (125 items, 44 minutes).

Part 1. (20 items, 15 minutes.) Simple arithmetical relations which appear in chemistry.

Part 2. (30 items, 12 minutes.) Three paragraphs are presented covering college textbook material in chemistry, followed by precise questions which measure the student's ability to read exactly and to resist generalizations.

Part 3. (15 items, 12 minutes.) A measure of chemistry reading comprehension which, for correct answers, requires a grasp of the ideas and relations involved.

Part 4. (60 items, 5 minutes.) Interest in chemistry is measured by simple factual questions of the true-false type which indicate the accuracy of the student's general knowledge of chemistry. Students with a particular fitness and liking for chemistry acquire this knowledge incidentally.

Chemistry Training, CT–1 (152 items, 43 minutes).

Part 1. (45 items, 8 minutes.) Knowledge of fundamentals of chemical processes.

Part 2. (45 items, 12 minutes.) Covers valencies, formulas, names of compounds, and the completion and balancing of equations.

Part 3. (50 items, 8 minutes.) Manufacturing processes and the applications of chemistry.

Part 4. (12 items, 15 minutes.) Fundamental chemical problems in which the mechanics of arithmetic are reduced to a minimum.

The examinations are administered in accordance with a procedure given in a Manual of Directions furnished to teachers giving the tests. Specified time limits are set on each part of each examination and the students are required to pass to the next part upon expiration of the designated time. At the end of the time permitted for each complete examination, papers are collected. The papers are scored by use of a scoring key in which the correct answers are supplied. Scoring is essentially a clerical process and is done rapidly by comparison of the answers with the key. Items are marked either correct or incorrect and no part credits are given. The total score in the true-false tests is obtained by subtracting the number of incorrect answers from the number of correct answers, the minimum score being zero. The total score on a given examination is the weighted total of the scores on the several parts, each part being assigned a weighting as indicated in the key. With the exception of the language and mathematics training examinations, scoring may be done by one not familiar with the subject matter.

General Purposes of the Examinations. It should be understood that the primary purpose that the examinations are designed to serve is the measurement of probability of scholastic success; specifically, the measurement of those factors that have important bearings upon the likelihood of success *in the freshman year*. Since, as has been amply demonstrated, scholastic ability is, in general, a quite permanent quality, any instrument that measures factors contributing to success in the freshman year will also be indicative of success in later years of the curriculum, though possibly not to the same degree due to the operation of a number of influences which lie beyond the scope of educational measurement. No definite attempt was made in constructing the examinations to measure factors contributing to success in engineering after graduation, except in so far as such success is indicated by scholastic achievement.

Another purpose of the examinations is that of indicating individual differences among entering students. If this is accomplished adequately, it is an important contribution to educational practice in view of the heterogeneity of the product of secondary schools entering college, and it is of particular importance in the case of students beginning the study of engineering with its exactions and inherent difficulties. Information of this character, when accurately determined and used with discretion to advise and guide both the able and the weak students, may aid in the solution of some of the most difficult problems of student personnel.

While the intention is to have the examinations serve these purposes, they should be regarded only as tools. Examination scores, by themselves, can not be expected to do anything. It is only when the results serve as the basis of improvement that they are of real value. Among the ways in which indications of student abilities and preparation may be employed are: early elimination of the demonstrably unfit; separate classes or sections for the poorly prepared but able; greater opportunities for the gifted and well prepared—all of these, and others, are measures which may be taken as a result of the examinations.

Validity and Reliability of the Placement Examinations. Inasmuch as the placement examinations comprise a series of mental and educational tests designed to measure certain facts, there are points concerning their ''internal behavior'' which should be examined; it is necessary to go beyond the previous statements which simply summarize their content in a general way.

The first and most important question is: Do the examinations really perform the functions for which they were devised? In order to give an adequate answer to this question it must be established that:

The examinations reveal individual differences in aptitude and training for the various subjects among entering students.

The examinations predict, to a useful degree, the subsequent performance of students in each subject.

The examinations can be used successfully in sectioning classes, in treating individual delinquencies and in various other aspects of personnel work.

There is a real distinction between *training* and *aptitude.*

The examinations are reliable, that is, are consistent in their measurements.

These points will be discussed briefly in the following pages. In following the discussion it should be borne in mind always that the criterion upon which the results of the placement examinations have been evaluated is, in almost every instance, scholastic achievement in college as measured by instructors' grades. These grades are to a certain extent, in fact in many instances to a large extent, subjective, and their accuracy as an index of student achievement is relatively low. This, it appears to the writers, is particularly true of the grades of students on the border between passing and failure since, and rightly perhaps, the instructor often ''gives the student the benefit of the doubt.'' The use of instructors' grades as the criterion against which to judge the accuracy of prediction of scholastic achievement given by the placement examinations is, of course, inevitable in view of present practices, but it may be pointed out that when the scores of the placement examinations are compared with the scores in comprehensive examinations of the objective type given at the end of the first semester of the freshman year, the correlation is materially improved. This condition should be remembered in connection with many parts of the discussion and in particular with reference to such data as those presented in Table 4, page 47 of the Appendix.

Individual Differences. The results of the tests indicate clearly that students vary tremendously in the skills and abilities represented in the examinations, ranging from scores close to zero to almost perfect performances. Figure 1, which depicts the range of scores in a single division of the examinations, chosen as representative of all, and Table 2 (Appendix, page 42), which summarizes results in all parts of the tests, indicate the spread in performance among a large group of students representing all sections of the country. Thus, in the Chemistry Aptitude Test, the highest one per cent of the students scored 98 or above while the lowest one per cent scored only 10 or below. The total number of students taking this test was 5,917. Similarly in the Chemistry Training Test, the lowest one per cent of the students scored only 2 or less, while the highest one per cent scored 152 or more. When

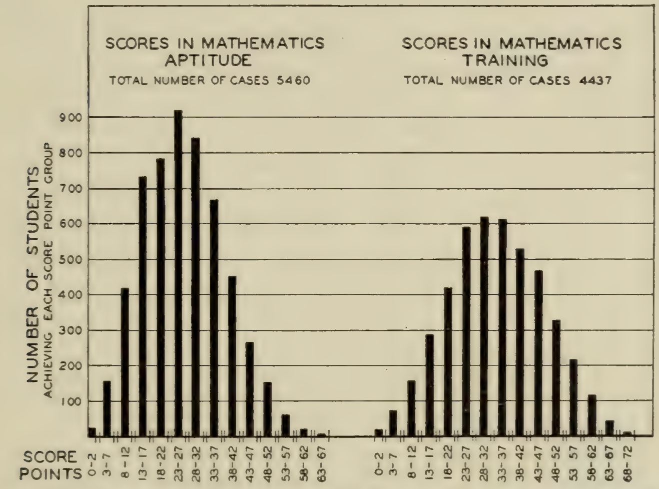

FIG. 1. Frequency Distribution of Scores in Mathematics Tests.

it is recalled that every student who took the Chemistry Training Test had studied chemistry in high school, presumably for a year, this difference in the knowledge of the elements of chemistry is astonishing. A similar extreme variation in performance is the rule for all the other examinations. If this range be discounted somewhat because of possible inability of some students to adjust themselves to the conditions of this sort of testing, nevertheless, the divergence is very great and indicates that the tests do measure adequately differences of individual performance.

Since these observed differences are accompanied by associated differences in scholastic achievement, as shown elsewhere, they must be taken as meaningful variations in student talent. All observing teachers know that homogeneity in a class is not to be assumed because all of its members appear of about the same age and intelligence, and apparently have had about the same secondary education. Yet educational practices all too often overlook this fact. The placement examinations furnish striking proof that such homogeneity is superficial, that students actually finding their way into a single classroom represent all degrees of high school success and mental ability to do the work of the course, and, needless to add, of interest and persistence in meeting its demands. In many institutions admitting large numbers of students "on high school credentials," the recognition of these differences, and the adjustment of instruction accordingly is of paramount importance and is becoming increasingly recognized as such. It is not too much to say that lack of awareness of student differences is a major contributory factor in the maladjustment of beginning students, or that recognition of and provision for them may do much to minimize such maladjustment.

Prediction of Performance. The chief purpose that has been recognized for tests of the same general kind as the placement examinations is the prediction of the quality of future scholastic performance. As previously stated, the placement examinations are designed to furnish a prediction not only of quality of scholastic work in general but also of work in particular subjects. It is upon the accuracy of this prediction that the real usefulness of the examinations to teachers and administrators chiefly depends and the matter will, therefore, be discussed in some detail.

It must be remembered, in this connection, that certain factors in addition to the limitations of the examinations themselves operate to restrict the accuracy of such prediction:

The fact that mental and educational elements are not the only constituents of successful achievement; interest, personality traits, health, environment, etc., are of consequence and are only indirectly measured in tests of the placement type.

Temporary variations in the behavior of individuals due perhaps to the operation of a number of small causes.

Aid given to individual students through definite provisions therefor in the institution wherein counsel and guidance are devoted to improving the performance of students found deficient by the examinations will operate to lower the prediction given by the tests—and rightly so.

The unreliability of instructors' grades which, through inaccurate measurement of student achievement, makes the prediction appear less accurate than it really is.

The Pearson coefficient of correlation is commonly used to express the accuracy of prediction of any educational measurement and has been employed for that purpose in this bulletin. This coefficient expresses the degree of similarity or correspondence between two sets of measurements of the same or related quantities or events: for example, as in this instance, between the scores in placement examinations and grades in corresponding subjects of the first semester of the freshman year. The higher the value of the coefficient, the closer is the agreement between the two measurements, a coefficient of 1.0 representing perfect agreement, 0 representing no agreement, and — 1.0 representing complete divergence or disagreement.

The following table exhibits values of this coefficient for the several parts of the examinations.

Examination	Mean coefficient of correlation for all colleges reporting	Range of coefficient of correlation
Chemistry Aptitude	0.48 *	0.23–0.63
Chemistry Training	0.52	0.25–0.67
Chemistry Aptitude plus Chemistry Training	0.52	0.35–0.65
English Aptitude	0.46	0.25–0.69
English Training	0.54	0.28–0.67
English Aptitude plus English Training	0.52	0.33–0.74
Foreign Language Aptitude	0.52	0.36–0.73
French Training	0.56	0.45–0.65
Spanish Training	0.53	0.48–0.57
Mathematics Aptitude	0.46	0.16–0.65
Mathematics Training	0.51	0.34–0.65
Mathematics Aptitude plus Mathematics Training	0.51	0.37–0.71
Physics Aptitude	0.47	0.28–0.62
Physics Training	0.61	0.57–0.69 †

* All coefficients of correlation reported in this study were computed by the Pearson product-moment formula, through the variant printed on the Ruch-Stoddard Correlation Chart:

$$r = \frac{\frac{\Sigma xy}{N} - \left(\frac{\Sigma x}{N} \cdot \frac{\Sigma y}{N}\right)}{\sqrt{\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2} \cdot \sqrt{\frac{\Sigma y^2}{N} - \left(\frac{\Sigma y}{N}\right)^2}},$$

where

r = the coefficient of correlation,
x, y = variations from assumed means on the X and Y axes, respectively,
N = the number of cases,
Σ = summation sign.

This formula is equivalent to the one in which deviations are taken from actual means:

$$r = \frac{\Sigma xy}{N\sigma_x\sigma_y}, \text{ in which } \sigma \text{ (or S.D.) represents}$$

the standard deviation of the series. The standard deviation may be defined as the square root of the mean of the squared deviations from an arithmetic mean,

$$\sigma = \sqrt{\frac{\Sigma x^2}{N}}.$$

† Three colleges only.

It should be remembered in interpreting the correlation coefficients as measures of the predictive value of tests that it depends upon what is to be predicted whether a given coefficient, as say 0.50, is relatively high or relatively low. If actual place or rank in a class is to be predicted, for example if it is to be shown that a student is expected to rank eighth in a class of sixty, a coefficient of 0.50 is relatively low. If, however, the prediction is to be whether a student may be expected to achieve a grade of A or B, C or D, or E or F, that is, whether he is to be in the high, middle or failing group in his class, a coefficient of 0.50 is relatively high and indicates that the test may be expected to predict his scholastic achievement, quite accurately. Since this is the kind, or the *order,* of prediction usually desired by the college teacher and administrator and is the sort most useful in dealing with students, it is evident that the Placement Examinations possess good predictive value.

This is shown still more clearly by the following tabulations which indicate the grades in college subjects achieved by the students who placed in each tenth of the class in the scores on the Placement Examinations. Tabulations are reproduced for examinations in only two subjects; those for other subjects give about the same distributions.

Decile	CHEMISTRY APTITUDE First Semester Grades			CHEMISTRY TRAINING First Semester Grades		
	A + B	C + D	F	A + B	C + D	F
10	68%	31%	1%	70%	30%	0%
9	44	51	5	51	47	2
8	34	57	9	42	54	4
7	27	64	9	30	63	7
6	26	60	14	30	60	10
5	18	67	15	22	59	19
4	18	63	19	31	58	11
3	12	63	25	26	66	8
2	5	65	30	19	61	20
1	3	51	46	8	62	30
	Number of cases, 3,015			Number of cases, 634		

Decile	Mathematics Aptitude First Semester Grades			Mathematics Training First Semester Grades		
	A + B	C + D	F	A + B	C + D	F
10	55%	39%	6%	50%	43%	7%
9	48	41	11	36	56	8
8	38	55	7	30	55	15
7	25	58	17	28	58	14
6	22	63	15	15	63	22
5	19	59	22	25	58	17
4	22	59	19	9	60	31
3	9	60	31	7	58	35
2	12	57	31	5	50	45
1	7	42	51	0	39	61
	Number of cases, 1,931			Number of cases, 1,093		

In connection with the above tables it should be remarked that, obviously, the predictions of relatively high achievement or of failure are much more clearly indicated than is relative standing in the large group which normally constitutes the "middle" of the class. For example, only one per cent of those students who ranked in the upper tenth in the test scores on chemistry aptitude received a grade of *F* and failed to pass first semester freshman chemistry. This is but three students out of the three hundred who ranked in the upper tenth of the group in test scores. This proportion of cases is so small as to be accounted for by failures due to "external" causes, such as health, which are beyond the limits of this sort of educational measurement. On the other hand, almost one-half of the students in the lowest tenth on test scores failed the subject and only three per cent of this group, or nine students, achieved semester grades of A or B. The same thing, and to nearly the same degree, is shown by the rankings of students in mathematics. Approximately eleven hundred cases of students who took this examination (Mathematics Training) were tabulated, giving about 110 in each decile group. Only eight students in the upper tenth failed to pass first semester mathematics and over sixty per cent of those in the lowest tenth failed to pass.

If the grouping of students be made according to the quarters of the class instead of tenths in the Placement Examination scores the prediction of first semester grades is naturally improved. Table 3 (Appendix, page 44) gives this distribution for all of the several examinations. Tabulations of results on this basis indicate in every case that the proportion of students ranking in the first quarter in the Placement Examination scores who did not pass the first semester's work in corresponding subjects was quite low, ranging from none to a maximum of ten per cent, and that the probable placing in the lowest quartile of those who failed to pass is quite large, ranging from a minimum of twenty-eight per cent to a maximum of fifty-eight per cent.

The validity of the Placement Examinations as measures of future scholastic achievement in comparison with other tests is shown by Table 4 (Appendix, page 47) giving coefficients of correlation for a number of well-known tests. It must be remembered in considering this comparison that all of the tests except the Placement Examinations are intended to predict scholastic success in general, that is, for all subjects of a given year, and not to predict achievement in particular subjects. Correlations of the former kind invariably tend to be higher than those between test scores and grades in particular subjects, in fact considerably higher. In spite of this tendency the Placement Examinations furnish correlations which are at least as high as those of the other tests. Correlations between composite scores in the entire series of Placement Tests and general success in the work of the freshman year are available for only those few institutions which administered the entire group of tests. For such as are available, the composite scores correlate from 0.65 to 0.75 with general academic work of the first semester of the freshman year. The highest of these figures is for the Case School of Applied Science, an independent polytechnic institute having an unusually homogeneous and well-prepared group of entering students. In Table 4 it will be noted that the correlation coefficients of the tests cited with scholastic work of the freshman year range from a minimum of 0.13 to a maximum of

0.62. The pooled scores of the Placement Examinations therefore seem to be a more valid index of scholastic achievement than do the results of the other tests. Table 4 also affords a comparison between the prediction of first semester grades in specific subjects in college by a number of tests and also those given by the Placement Examinations, the data for the latter being those previously given on page 702.

Although it was not one of the purposes of the trial of the Placement Examinations, and although the examinations are not intended to predict scholastic performance throughout the college course, some data have been gathered indicating the way in which the tests do predict performance beyond the freshman year. These data are decidedly relevant if the Placement Examinations be considered as possible instruments for the admission of students to engineering colleges, for, in the last analysis, it is the success of students throughout their course that is important. The following tabulation compares the results of the Iowa Placement Examinations with the Army Alpha Test and the Council on Education Tests in predicting the survival of students throughout the four years of their course at the Case School of Applied Science. The table also shows the value of first semester freshman grades in predicting student survival. It will be noted that no student who placed in the upper fifth of the group in the Placement Examination scores failed to complete his course because of scholarship, that three-fourths of those so placing survived to enter the senior year, all causes of elimination being included, and that sixty per cent of those in the lowest fifth of the class dropped out of college because of scholastic failure—a remarkable prediction. It is also to be noted that the Placement Tests are almost as efficient in predicting scholastic survival as are first semester freshman grades. Similar results as to the predictive value of the Iowa Placement Tests are given by data supplied by the Missouri School of Mines, not reproduced here.

PREDICTIVE VALUE OF TESTS GIVEN CLASS OF 1928 ON THEIR ENTRANCE TO COLLEGE CASE SCHOOL OF APPLIED SCIENCE

Army Alpha Test — Given September, 1924
Number of cases 188

Standing on Test	% in Senior Class	% Out, Scholarship	% Out for Other Causes
Highest fifth	60	16	24
Second fifth	45	34	21
Third fifth	53	21	26
Fourth fifth	31	50	19
Lowest fifth	21	58	21

Council on Education Tests — Given September, 1924
Number of cases 189

Highest fifth	71	6	23
Second fifth	52	25	23
Third fifth	44	36	20
Fourth fifth	22	53	25
Lowest fifth	28	54	18

Iowa Placement Tests — Given October, 1924
Number of cases 185

Highest fifth	77	0	23
Second fifth	50	27	23
Third fifth	44	33	23
Fourth fifth	23	49	28
Lowest fifth	19	60	21

Predictive Value of First Term's Grades — February 1, 1925
Number of cases 193

Highest fifth	76	0	24
Second fifth	54	14	32
Third fifth	51	21	28
Fourth fifth	21	56	23
Lowest fifth	3	85	12

Sectioning of Classes; Personnel Work. The utility of the Placement Examinations as a means of sectioning classes is dependent upon their ability to measure those individual differences in test performance that are associated with differences in subsequent scholastic achievement. The success of the tests in this connection is indicated by the foregoing paragraphs. A single illustration, drawn from the numerous data available, will serve to indicate the validity of sectioning on the results of the Placement Examinations. A class of 166 students was given both the training and aptitude tests in chemistry. First semester grades of these students are shown in the following tabluation:

Quarter of Class in Placement Examination Scores	Semester Grades in Freshman Chemistry		Pass	Non-Pass
	A, B %	C, D %	%	%
1 (Highest)	67	33	100	0
2	35	51	86	14
3	24	39	63	37
4 (Lowest)	2	45	47	53

This table indicates a notable scholastic superiority of the upper quarter, scholastic inferiority of the lowest quarter, and moderately successful accomplishment for those standing in the middle half of placement examination performance, this being the order of distribution usually desired in the several sections of a given class.

As to the advisability of the practice of sectioning classes, it may be said that experiments designed to test the value of this procedure accurately under controlled conditions are few; at the present time, the case for sectioning rests largely on the personal opinions of instructors who have worked with sectioned and unsectioned classes. The inquiry conducted by Dean C. E. Seashore for the American Association of University Professors * indicates a generally favorable attitude of instructors and administrators toward some plan of sectioning. Similarly, the authors in correspondence with users of the Placement Examinations have secured some subjective evidence of the effectiveness of sectioning, though the opinions were by no means unanimous.

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* *Sectioning on the Basis of Ability*, by C. E. Seashore; A report by Committee G of the American Association of University Professors, Bulletin of American Association of University Professors, Volume IX, Number 6, October, 1923.

In a recent publication Professor James B. Tharp * of the University of Illinois reports the use of Placement Examinations in connection with courses in French. This study is one of the few trial experiments on the effects of sectioning and the value of the Placement Examinations in connection with that practice. Professor Tharp writes as follows:

"The experimental (*i.e.*, sectioned) classes gained the value of + 0.35, or about one-third of a letter grade over the non-sectioned classes. Moreover the 'middle-low' group has received a greater benefit from the division than the 'high' group since it gained + 0.64, nearly two-thirds of the letter grade. Opponents of sectioning have always claimed that average and poor students need the presence of their more brilliant fellows to inspire them to greater effort. This evidence indicates the exact opposite; that both groups are benefited by being separated and the less brilliant much more than the superior students."

The analysis of the utility of the Placement Examinations in individual personnel work is somewhat outside the scope of this bulletin, for the procedure of such work usually involves more or less elaborate case histories which are not amenable to brief summarizing. The ways in which the examinations are of use to personnel advisers are given in detail in the studies by Lemon † and by Remmers.‡ In these investigations the Placement Examinations gave specific information as to individual differences in ability along special lines of a type not available from a general intelligence test and were found serviceable in dealing with individuals.

Aptitude vs. Training. As will be readily appreciated, the division of the tests into two series, aptitude and training, arose in part from the practical necessity of testing students who, though without previous schooling in a particular subject, such as chemistry or physics, nevertheless would enter upon the study of those subjects in college. Moreover it appeared desirable to differentiate the two types of ability in other subjects, such as mathematics and English, which all students present for admission, in order to improve the prediction obtainable by either type and to furnish for the college teacher information as to students possessing good general ability but poor preparation and also to point out those of good training but mediocre ability. There is, of course, a clear distinction between aptitude and training in all cases wherein a student may successfully undertake one test but not the other. Thus, a student without previous training in chemistry or physics will score approximately zero in the training tests on these subjects, but may secure high scores in the corresponding aptitude tests. Where both aptitude and training tests are given to students qualified to take both series a positive correlation between the results will be found but the correlation is not as high as that between different forms of the same aptitude or training examination. The correlation between aptitude and training tests varies from 0.54 to 0.58 while the reliability coefficients (to be explained later) range between 0.82 and 0.97. Thus while the tests do show positive correlation between the results on the aptitude and training examinations, the correlation is considerably less than that between forms of the same test, indicating that, to some degree, different qualities of the students are measured by the two examinations. It may also be pointed out that the aptitude test in a particular subject predicts performance in that subject better than it does in any other subject.

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* *Sectioning Classes in Romance Languages,* by James B. Tharp; The Modern Language Journal, Volume XII, Number 2, November, 1927.

† Lemon, A. C. "An Experimental Study of Guidance and Placement of Freshmen in the Lowest Decile of the Iowa Qualifying Examination, 1925"; *University of Iowa Studies in Education,* Volume III, Number 8, February 1, 1927.

‡ Remmers, H. H. "A Diagnostic and Remedial Study of Potentially and Actually Failing Students at Purdue University," *Purdue University Studies in Higher Education* IX, May, 1928; 164 pp.

It may be asked, and properly, what grades of scholastic work are achieved by students having low scores on the aptitude tests and high scores on the training tests and by students making high aptitude scores and low training scores. A certain number of cases were selected for analysis and indicate the following, in general, the examinations being those in mathematics:

Of the students achieving high scores in both aptitude and training, about 55 per cent made A or B in freshman mathematics, slightly more than 40 per cent made C or D, and 4 per cent failed. No students who made low scores on both aptitude and training tests achieved A or B, 41 per cent achieved C or D, and 59 per cent failed. The students achieving low scores in the aptitude test and high scores in the training test were about equally divided among the three groups mentioned; about one-third in the A and B group, one third in the C and D group, and about one-third in the failing group. All the students who scored high in the aptitude but low in the training test were placed in the middle group of C and D grades in the freshman year—an indication of the handicap that the able student carries by reason of poor preparation. These results seem to be about what might have been anticipated of a valid test designed to measure aptitude and training separately and show in a general way that the tests performed their function properly. The number of cases analyzed for this illustration, however, is not large enough to warrant the drawing of any final conclusions and the data are not reproduced here in tabular form for that reason.

Reliability. Technically, the term reliability as applied to educational tests may be thought of as the consistency with which the test measures whatever it does measure. Reliability may be expressed quantitatively in two ways: (*a*) as a coefficient of correlation, and (*b*) as a probable error which shows the deviation of scores in the tests from hypothetical scores based on the mean of a very large number of cases. Since this bulletin is based only on Form A of the Placement Examinations, coefficients of reliability were computed by the so-called chance-half method. Reliability data for Series 1, Revised, Form A are given in the following table.

Name of Test	Coefficient of Correlation	Number of Cases	Standard Deviation (S.D.)	Probable Error of Score (PEscore)	$\frac{\text{PE}_{\text{score}}}{\text{S.D.}}$
CA–1......	0.88	100	17.5	4.0	0.23
CT–1......	0.93	100	28.0	5.1	0.18
EA–1......	0.82	100	9.2	2.6	0.29
ET–1......	0.90	100	34.3	7.3	0.21
FA–1.......	0.97	100	26.7	3.1	0.11
FT–1.......	0.93	100	28.1	5.0	0.18
ST–1.......	0.82	100	16.7	4.8	0.29
MA–1......	0.86	100	7.0	1.7	0.24
MT–1......	0.88	100	10.4	2.4	0.23
PT–1.......	0.85	100	24.4	6.4	0.26
PA–1.......	0.89	100	19.0	4.2	0.22

The correlations listed above are typical of those usually found for examinations of the objective type. All computations are based on a single sample of beginning college students.

The standard deviation (S. D.) is the square root of the mean of the squares of deviations from the arithmetic mean of the scores.

The meaning of the probable error of score may be made clear by referring to the entry for Chemistry Aptitude CA–1. The value of 4.0 indicates that a score of say 60 is really a variable, such that fifty per cent of the time the score 60 will fall in the range 60 ± 4. Similarly since the scores follow a normal distribution the chances are 4.5 to 1 that the true score lies within the limits 60 ± 8; 21 to 1 that it lies within the limits 60 ± 12, etc. In this instance, then, it is reasonably certain that the score 60 could not under any changed conditions of sampling be less than 48 or more than 72.

Since the score units vary from test to test, the probable errors of score are not directly comparable measures of reliability but they are made comparable by the device of expressing each probable error and the corresponding standard deviation as a ratio; the smaller this ratio the more efficient the examinations.*

Comparison of Results of Placement Examinations in

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* See Ruch and Stoddard, *Tests and Measurements in High School Instruction,* World Book Company (1927), Chapter XX.

Various Institutions. Greater differences of results in the Placement Examinations among various colleges are exhibited than might have been anticipated. This is true to a greater degree of the training than of the aptitude tests. Generally speaking, colleges in industrial and more thickly populated areas report higher scores on both parts of the tests than do colleges in rural sections. (It must be remembered, in this connection, that engineering colleges draw their students from areas quite close to the institutions, the median radius being about one hundred miles. See Bulletin Number 1 of the Investigation of Engineering Education.) Presumably students in the more thickly populated sections of the country received their preparation in the larger and better equipped and better staffed public schools of the cities, whereas students, from rural communities come from the less well equipped rural schools. In the examinations in mathematics the five institutions reporting the highest median scores are in industrial sections, whereas the five reporting the lowest scores are all in non-industrial localities, and all but one of these are in the South. The range of median scores reported by the colleges is considerable in all of the examinations but is greatest in the sciences, physics and chemistry. This is to be expected, since it is in these subjects that the laboratory facilities that are needed for effective work are often lacking in the smaller schools.

Of greatest significance to engineering colleges, probably, are the results in mathematics. In the aptitude test the median scores reported range from a maximum of 39.36 to a minimum of 19.16. In the training test the range is from 51.50 to 24.08. In both cases this is approximately a ratio of two to one.

In other subjects the range of median scores is even greater as indicated by the following tabulation which includes only those institutions that administered the tests to students of engineering:

Examination	Highest Median Score	Lowest Median Score	Approximate Ratio
Chemistry Aptitude	79.46	40.28	2 : 1
Chemistry Training	99.15	39.05	2.5 : 1
English Aptitude	47.93	32.09	1.5 : 1
English Training	109.95	59.50	1.85 : 1
Mathematics Aptitude	39.36	19.16	2 : 1
Mathematics Training	51.50	24.08	2 : 1
Physics Aptitude	142.34	108.07	1.3 : 1
Physics Training	91.09	36.00	2.5 : 1

(The number of institutions administering the foreign language tests to engineering students was so small as to make statements of maximum and minimum scores misleading.)

In a discussion of the results of the Placement Examinations in chemistry, Cornog and Stoddard * say as to this situation: "In a general way the scores (in the Aptitude Test) represent the native capacity of the freshman groups at the institutions named to accomplish whatever is required of them in the pursuit of a first course in freshman chemistry. A notable feature of this table is the rather narrow limits between which the mean scores fluctuate. East, West, country or city, large institution or small—the student in the middle of the class most often makes a score not varying widely from 60. This indicates that freshman chemical aptitude is much the same everywhere and that no college represented has a notable initial handicap or advantage in the quality of its starting material.†

"Similarly Table V contains mean scores (This table, Number 5 of this bulletin, with additional institutions not reported upon by Cornog and Stoddard will be found in the Appendix,

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* "Predicting Performance in Chemistry;" *Journal of Chemical Education,* Volume 3, No. 12, December, 1926.

† In the above table it appears that the ratio of highest to lowest median scores reported by the colleges for the Chemistry Aptitude Test is approximately 2:1. This ratio would be reduced to approximately 1.7:1 by the omission of the results from one institution. The inferences drawn by Cornog and Stoddard as to the range of aptitude in chemistry among freshmen is warranted by a more detailed study of the data than is afforded by the mere statement of the ratio of highest to lowest median score. Ed.

page 736) obtained from the use of the Chemistry Training Examination at the institutions mentioned in the table.

"Table V affords an index of the thoroughness of the chemical training given by high schools to the students in the various groups represented.

"A study of Table V reveals the fact that, in any column in the table representing average group scores, the highest value is just about double the lowest. Further observation shows that the average score of the lowest fourth at some institutions is higher than the average score of the highest fourth at others. No merit or lack of it on this account applies to the institutions concerned, since the thing measured is retention of chemistry learned in high school before coming to college. Whatever may be the causes of the conditions indicated, the fact remains that the problem of utilization of high school chemistry as a basis for a differentiated freshman chemistry course will be a very different problem at different institutions. Further, the spread of scores in single institutions is such as to raise the question of the advisability of giving the same course to all who offer entrance credit in chemistry."

Continuing the above argument it is fair to ask, in view of the divergence of results shown by various institutions and by the range of scores among their students, whether it is sound practice to place all of these students in college courses at the same starting level, especially in mathematics and the physical sciences. The evidence indicates that there is a considerable range of quality and extent of preparation among institutions and, as before stated, among students in the same institution. Presumably, and the presumption may be supported by evidence, many of the poorly prepared students possess good native ability as well as traits of perseverance making for success in college work. Started at the right level and carried along at a pace they are capable of sustaining, such students may go far. Forced to adhere to a general standard beginning level and to carry the same work as those better prepared, such students may, and do, become discouraged, lag behind, and eventually drop out of college under the stigma of failure. The question of organization of freshman classes is beyond the scope of this bulletin, excepting only as the results of the Placement Examinations have a bearing upon it, and will not be discussed further. The problem is a very important one, however, and the above facts, as well as others to be deduced from the tabulations of data, are presented for whatever light they may throw upon the situation.

Table 5 (Appendix, page 736) summarizes data on the results of the Placement Examinations reported by all the colleges offering engineering courses.

Quality of Students' Preparation as Indicated by Results of Placement Examinations. The results of this study afford quite a little information upon the question of the extent and quality of the preparation of students entering engineering colleges throughout the country. It is the intention to discuss this phase of the results, one of the important reasons for undertaking the project. Since the figures speak plainly for themselves, comment will be relatively brief.

The following tabulations give the number of correct and incorrect answers and the number of times omitted for selected questions of the training examinations in three subjects—mathematics, chemistry and physics. The questions were selected, in general, because they are typical and because in many instances they deal with fundamental concepts, laws or processes which are believed to be essential as basic preparation for the successful pursuit of the subject. Only comparatively simple questions were selected; those that seemed more difficult were omitted. In general the questions selected were distributed fairly evenly throughout the several tests. The number of times the answer to any particular question was omitted is, of course, influenced to a certain degree by the position of the question in the whole group; those occurring toward the end would naturally be omitted oftener than those occurring near the beginning. It is believed that this element has been guarded against properly in selecting the questions. It should be remembered that the institutions represented in the summaries are located in all parts of the country, that they include all types of colleges offering engineering courses, and that there is a fair division between institutions in urban and in rural communities. The figures, of course, represent average conditions; there are fairly striking deviations from the average.

SELECTED QUESTIONS FROM MATHEMATICS TRAINING, MT–1

	Right	Wrong	Omitted	Total	% right
1/8 plus 5/8 equals how many hundredths?	1,005	425	104	1,534	65.6
Divide 8/15 by 3.2	637	348	549	1,534	48.0
Simplify: $\frac{3.12}{\sqrt{.04}}$	343	434	754	1,531	22.5
Perform the multiplication $(a^2bc^4)^3$	968	414	142	1,524	63.5
Add: $\frac{1}{a}+\frac{1}{b}$	822	629	83	1,534	53.6
The lateral area of a circular cylinder is approximately 3.1416 times the altitude (to be marked *true* or *false*)	972	450	112	1,534	63.4
The perimeter of a square is $4y$. What is the diagonal?	648	683	203	1,534	42.3
Write a formula which gives the cost c in dollars of m miles of wire at d dollars a pound, if one foot of wire weighs p pounds	464	714	356	1,534	30.2
The quotient of two numbers, x and y, is 2, and the larger exceeds the smaller by 7. Find the numbers. (Equations only)	299	285	950	1,534	19.5

On this examination (Mathematics Training), for which a perfect score is 75, the median score of 1534 students was approximately 37.5, or 50 per cent, stated in the usual manner of grading. The highest median score reported by an institution was approximately 50, and the lowest approximately 25. The maximum score reported for any individual student was 70.

The following illustrations are typical of the results in chemistry:

	Right	Wrong	Omitted	Total	% right
Nitrogen is a very active element. (To be marked *true* or *false*)	353	149	27	529	66.7
Anhydrides are a group of minerals. (To be marked *true* or *false*)	388	57	84	529	73.4
Write the valence of SO_4	251	47	231	529	47.5
Write the formula for copper sulphate	373	82	74	529	70.5
Write the formula for lime (unslacked)	121	179	229	529	22.8
Complete and balance $KOH + HCl$	365	44	120	529	69.0
Complete and balance $2Al(OH)_3 + 3H_2SO_4$	89	187	252	528	16.8
If 7 gm. of iron unite with 4 gm. of sulphur, how many gm. of iron sulphide will be produced?	363	57	109	529	68.6
The atomic weight of H is 1; of Cl, 35.5; of Zn, 65. What weight of Zn will be needed to generate 10 gm. of H, using dilute HCl?	89	114	326	529	39.2

Commenting on the results of this examination, Cornog and Stoddard (See reference on page 714) say: ''In a group where 31 per cent fail to complete and balance $KOH + HCl$ . . . we believe we are warranted in assuming that a third of the group learned nothing of equation writing or chemical arithmetic while in high school.* High school chemistry teachers may find comfort in the fact that if many freshmen got through high school without knowing much about chemical arithmetic, there was also a large number who got through without knowing much about *any* arithmetic as is evidenced by data gathered from the Mathematics Training Examination.''

In physics the results are even more striking and, we are impelled to say, discouraging. Consider the following tabulation giving results on typical questions of the Training Examination. All of the 534 students taking this examination had had physics in high school.

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* In view of results on other questions, this seems to be a very conservative statement as to the percentage not having the ability named. Ed.

	Right	Wrong	Omitted	Total	% right
—— is the rate of doing work	130	216	188	534	24.4
The heat developed in a conductor is proportional to the —— of the current	53	274	207	534	10.0
The intensity of light is inversely proportional to the square of the distance between the source of light and the illuminated object. (*True* or *false*)	247	231	56	534	44.8
The fall of potential along a conductor is inversely proportional to its resistance. (*True* or *false*)	116	185	233	534	21.8
In Boyle's Law, PV = ——	251	119	164	534	47.0
In Ohm's Law, I = ——	157	109	268	534	29.4
If 10 divisions on a vernier cover 9 mm. on a millimeter scale, the smallest division that can be measured is (in mm.)	88	253	193	534	16.5
A body submerged in a liquid is buoyed up by a force equal to the weight of the liquid displaced by it. (Name of the law to be stated)	204	72	258	534	38.2

One may ask, in view of the above results, which are typical of those throughout the examinations: What *do* students learn of physics in the high school? If they do not, at the very least, know the statement of Ohm's Law, to say nothing of its use, what *do* they know of electricity and magnetism? If they cannot tell how a simple vernier is read, what *do* they know of physical measurements? If they do not know that power is the rate of doing work, what *do* they know of mechanics? The answer, we fear, is that the college teacher of physics cannot assume any beginning knowledge on the part of most of his class. As a matter of fact, this is the actual case in most institutions, and the teaching of physics to engineering students is adjusted accordingly. But the question remains: What did the student do with his year's work in physics in the high school? Has he any mastery of what he has covered; does he have any conception of quantitative relations; has he had any discipline in thinking intensively about the materials that he has had placed before him by his teachers? The answers to these questions are of vital interest to engineering teachers.

No one would claim, of course, that the results of a single examination can give an accurate picture of the values of secondary education in this country. But they can and do throw some light upon the causes of the difficulties with which teachers of engineering freshmen and sophomores are struggling. For better or worse the colleges of engineering are bound to depend upon the high schools for their recruits. Is it not fair to ask whether the work of the high schools should, to a reasonable degree, be designed to lay the foundation for the work that the student must carry on in college? Do the results of this study as cited above indicate that such is the case?

Sectioning of Classes on the Basis of Ability. Quite a little has been said in the preceding paragraphs concerning this matter and it may now be well to summarize those aspects of sectioning upon which the placement examinations have a bearing. The case for sectioning appears to rest in principle upon answers to the following questions:

(1) Is there sufficient heterogeneity in the class to justify the establishment of sections of students of different grades of ability and preparation?
(2) Can a sufficiently accurate means of measuring differences among individual students be found?
(3) Will the students benefit by the practice; will the superior, the average and the weaker students all benefit?

If sectioning on the basis of ability be established as desirable in principle certain other questions which present themselves when the practice is to be instituted must also be answered:

(4) What are the administrative difficulties and how can they be met? (Such questions as scheduling the class hours in various subjects; provision for promoting and

demoting students during the semester so as to insure proper placement, and the like.)

(5) What is the best number of sections; shall there be a superior group, a middle group and a low standing group, or shall there be more or fewer classifications?

(6) Should students be sectioned for each subject according to probability of success in it or will a single sectioning for all subjects in a given semester be sufficient?

(7) What different ways of dealing with the several sections should be employed; in particular, if the superior students are to be given greater opportunity shall this take the direction of more ground to be covered or shall the same ground be covered in a different way?

(8) How shall the teachers be assigned to the several sections; should the ablest take the best or the poorest sections?

(9) Should there be a minimum standard of performance and a minimum requirement of material to be covered by all students irrespective of the section in which they are placed or should the standards be adjusted, more or less, to accord with the capabilities of the different sections?

These questions do not exhaust the possibilities among those that might be asked here but they indicate the sort that arise when the practice is under consideration either in principle or from the standpoint of the everyday working of the institution.

As to the first question above, we believe that the experience of teachers, as well as the evidence adduced herein prove that college students, particularly freshmen, are of such a wide range of abilities and preparations as fully to warrant the establishment of sections of different grades of ability. This is undoubtedly true, though perhaps not to the same degree, of students in institutions of all kinds, not only the publicly supported university that must by legal enactment admit all graduates of accredited high schools, but also of the privately endowed college which exercises more or less discrimination in admitting candidates. Further, it is true, as demonstrated by the data of this study, even of institutions admitting comparatively small classes. In brief, there can be no reasonable doubt as to the validity of sectioning if it rest on the basis of heterogeneity of students only.

As to the discovery of instruments for differentiating students, we believe that those which predict scholastic achievement in particular subjects serve the purpose to better advantage than those designed to measure academic success in general in view of the way in which college work is conducted. The extent to which the Iowa Placement Examinations serve as valid measuring instruments is stated in the preceding paragraphs. For subjects of the second semester of the freshman year or for those of later years the grades in preceding semesters in the same or related subjects may be employed even though under the traditional methods of grading the grades are relatively inaccurate. Examinations of the objective type administered at time of admission will not measure, except indirectly, such important points as personality traits, environment, health and other factors, but these are included in considerable measure in semester grades. To summarize, we feel justified in saying that if classes are to be sectioned, means of doing so in a satisfactory manner are now available.

Of course the final answer to the question of sectioning depends upon the benefits which the practice brings to students and teachers. A considerable amount of subjective evidence in the form of opinions by teachers who have followed the practice of sectioning is available and it is, in general, favorable. The experimental work reported by Miller,[*] Tharp (19)[†], Young (20), and Cornog (2) are more objective measures of the results of sectioning. The results obtained by Tharp have already been quoted in this bulletin (see page 21) and the reader is referred to the other references in case he wishes to examine further into the matter. So far as the evidence warrants us in drawing conclusions it may be said that all sections of a class benefit from sectioning; the superior, the average and the weak students alike.

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[*] Miller, H. W. (University of Michigan), ''Segregation on the Basis of Ability.'' *School and Society,* Volume XXVI, Number 655 (July 16, 1927), pages 84–88; (July 23, 1927), pages 114–120.

[†] Figures in parentheses refer to item numbers of the Bibliography (Appendix, page 741).

That the administrative difficulties connected with sectioning can be surmounted in almost all instances is clearly indicated by the rapid spread of the practice among the colleges in the past few years.

Limitations of Placement Examinations. Some of the limiting factors in the employment of the Placement Examinations for the ends which have been advanced previously in this study are already implicit in the discussion. They may be summarized at this point as a means of checking too great expectations and in order to suggest further supplementary lines of investigation.

(1) The examinations are brief (each test comprises about 40 minutes' working time) and they are imperfect. Hence where important decisions regarding individuals are involved it will be best to give both forms, A and B. This doubles the testing time, and increases the reliability as shown in Table 6 (Appendix, page 740). Where time is not a prime factor (e.g. in building up an elaborate case history) the best procedure is to give the student both forms of every examination which has any bearing on his case.

(2) The examinations measure certain important traits of character and personality only in an incidental manner. Thus persistence is a differentiating influence between scholastic success and failure. Similarly interest in the work, drive, resistance to outside distracting influences, emotional stability, methods of study, etc., while they are not names of specific traits, nevertheless connote behavior patterns which have varying weight in determining actual achievement. They are measured by the Placement Examinations only to the extent that performance in these is somewhat conditioned by the operation of such factors during both the learning period (that is to say in high school or preparatory school) and the testing period. Of especial interest here is the finding of May * that

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* May, Mark A., "Predicting Academic Success." *Journal of Educational Psychology,* Vol. XIV, No. 7 (October, 1923), pages 429–440.

prediction of college success by means of an intelligence examination was significantly increased by taking into account the amount of time devoted to study. The fact that the most intelligent tended to study less than the others lowered the observed correlation between test-scores and college achievement. Hence administrators and counselors interested in securing optimum prediction of success during the first few days or weeks of college attendance must be prepared to embark upon a rather extensive investigation of the complete personality of individual students, together with a careful study of the new scholastic milieu in which they are to be active. At best there will be sufficient departure from predicted results to prevent monotony and forestall any strictures as to the deterministic nature of the program! Moreover as has been pointed out by Brigham * and by Stoddard (16, page 714) to the extent that early remedial measures (such as elimination, sectioning, counseling) are applied, we may expect a decrease in the correlations representing such prognosis.

(3) Human achievement in any field is in part the resultant of forces which operate in a fickle and temporary fashion. Measurement in September, no matter how perfect it may become, cannot take complete account of conditions and forces which intervene in the life of the student between September and January—some of these influences (such as illness, accident, financial loss) are simply not in the individual or environmental pattern at the beginning.

(4) Finally the college marks which are taken to represent achievement are not themselves very reliable. As a result, when the Placement Examinations are used to predict scores in comprehensive, objective semester examinations in a subject, the correlations are noticeably increased—see, for example, Stoddard (16) and Tharp (19). Similarly a satisfactory prediction of pooled academic grades is a less difficult problem than prediction of grades in a particular subject. Improvement here must come through the utilization of better

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* Brigham, C. C. (Chn.). *Scholastic Aptitude Tests*—Manual; page 8.

achievement examinations in conjunction with the adoption of a more uniform policy of marking on the part of instructors.

Conclusion. It may be well in this concluding section briefly to summarize some of the more important conclusions drawn on the preceding pages.

One of the facts that the results of the study indicate clearly is the great range of aptitude and preparation possessed by entering students, both for scholastic work in general and for specific subjects in particular. All thoughtful teachers realize this, of course, but educational practice all too often fails to provide for it and to adjust the starting level of college courses and the pace maintained in them to accord with student capacities.

Another factor indicated by the data, one that might not have been anticipated by some, is the considerable range of median scores on the examinations reported by various institutions. This range is greater in the case of the Training Tests than in the Aptitude Tests, but it is significant in both.

The Placement Examinations appear to be valid instruments for the prediction of scholastic achievement in college. The prediction appears to be best among the highest ranking students, good as to the lowest ranking students, and, as might have been expected, lowest as to the students near the middle of the group. Since it is the ablest and the poorest students whom it is usually desired to differentiate, the examinations appear to serve their purposes as means of predicting college work adequately. While not primarily intended to serve as means of predicting work beyond the freshman year, the results reported by institutions which supplied information indicate good prediction of student survival throughout the undergraduate course. We surmise that this prediction is best where factors extraneous to scholarship are least operative.

From the evidence adduced it appears that the Placement Examinations furnish valid data for the sectioning of classes on the basis of ability. Such data are also valuable as parts of case histories in institutions which provide some form of individual personnel work.

The results of the examinations appear to throw considerable light upon the much mooted question as to the quality and extent of the scholastic preparation of students entering upon the study of engineering. If the situation can be summed up in a phrase, it may be said that the instructor of freshmen and sophomores can take nothing for granted in dealing with the fundamentals of his subjects.

While no attempt has been made fully to discuss the matter of sectioning on the basis of ability, the evidence cited is generally favorable to that practice. From the few controlled experimental studies that have been made of its results it appears that all students benefit, the poorest even more than the ablest. In connection with the practice of sectioning, one point not previously discussed may be mentioned. In many, in fact probably in most, institutions which do not require entering students to present credentials in physics and chemistry those who have pursued the subject in high school (and in the case of some urban high schools have had excellent preparatory training in them) are placed in the same sections with students who have had no preparation in them at all. The pace of the class, which is no doubt adjusted to the abilities of a majority of the group, is therefore entirely unsuited to those of good preparation and in many instances is equally unsuited to those of no preparation and of low aptitude. The result is no doubt equally bad both for the best and for the poorest students. Sectioning in accordance with preparation and aptitude appears to offer the remedy for this situation.

As a final word the authors would reiterate a statement previously made: that the results of tests such as the Placement Examinations, valuable as they may be simply as data, cannot by themselves accomplish anything. It is only when they are *used* for remedial measures that good can result.

APPENDIX

TABLE 1.

SUMMARY OF CONTENT OF THE TRAINING AND APTITUDE TESTS

CHEMISTRY APTITUDE, CA–1 (125 items, 44 minutes).

Part 1. (20 items, 15 minutes.) Simple arithmetical relations which appear in chemistry.

Part 2. (30 items, 12 minutes.) Three paragraphs are presented covering college textbook material in chemistry, followed by precise questions which measure the student's ability to read exactly and to resist generalizations.

Part 3. (15 items, 12 minutes.) A measure of chemistry reading comprehension which, for correct answers, requires a grasp of the ideas and relations involved.

Part 4. (60 items, 5 minutes.) Interest in chemistry is measured by simple factual questions of the true-false type which indicate the accuracy of the student's general knowledge of chemistry. Students with a particular fitness and liking for chemistry acquire this knowledge incidentally.

CHEMISTRY TRAINING, CT–1 (152 items, 43 minutes).

Part 1. (45 items, 8 minutes.) Knowledge of fundamentals of chemical processes.

Part 2. (45 items, 12 minutes.) Covers valencies, formulas, names of compounds, and the completion and balancing of equations.

Part 3. (50 items, 8 minutes.) Manufacturing processes and the applications of chemistry.

Part 4. (12 items, 15 minutes.) Fundamental chemical problems in which the mechanics of arithmetic are reduced to a minimum.

ENGLISH APTITUDE, EA–1 (65 items, 43 minutes).

Part 1. (20 items, 8 minutes.) Measures ability to comprehend and apply rules of grammar.

Part 2. (10 items, 8 minutes.) Measures ability to grasp compact material of the type found in college textbooks.

Part 3. (15 items, 12 minutes.) A measure of reading comprehension, with the emphasis placed on ideas rather than factual content.

Part 4. (20 items, 15 minutes.) Tests composition ability, through accuracy of analysis of a theme.

ENGLISH TRAINING, ET–1 (190 items, 40 minutes).

Part 1. (25 items, 8 minutes.) Twenty-five misspelled words are presented in a list of seventy-five words drawn from Standardized Spelling Scales.

Part 2. (60 items, 11 minutes.) A test of punctuation and sentence structure through recognition of right and wrong sentences.

Part 3. (60 items, 11 minutes.) A test of grammar with special reference to colloquialisms, barbarisms, and common errors of oral English.

Part 4. (45 items, 10 minutes.) A measure of the student's ability to distinguish between clear, emphatic sentences and those which are weak, confused or ridiculous.

FOREIGN LANGUAGE APTITUDE, FA–1 (150 items, 45 minutes).

Part 1. (50 items, 10 minutes.) A brief measure of elements of English grammar which deal with parts of speech, inflections, and roots.

Part 2. (40 items, 12 minutes.) Esperanto is employed to measure the amount of transfer from English to an unfamiliar language. Success in recognizing the significant words in the Esperanto sentences depends on the ability to grasp the meaning of the whole sentence.

Part 3. (30 items, 10 minutes.) Tests the ability to comprehend and apply grammar rules in an unfamiliar language (Esperanto).

Part 4. (30 items, 13 minutes.) A measure of aptitude for translation. The student observes a scrambled English translation of material in Esperanto and is asked for English equivalents, Esperanto equivalents, and parts of speech.

FRENCH TRAINING, FT–1 (160 items, 45 minutes).

Part 1. (60 items, 10 minutes.) A vocabulary test based on Henmon's word count.

Part 2. (40 items, 10 minutes.) Covers essential points in French grammar.

Part 3. (40 items, 10 minutes.) A test of important idioms and tenses of verbs.

Part 4. (20 items, 15 minutes.) A measure of French reading comprehension, in which three paragraphs of increasing difficulty are presented followed by questions to be answered in English.

SPANISH TRAINING, ST–1 (150 items, 43 minutes).

Part 1. (50 items, 8 minutes.) A vocabulary test based on Henmon's word count.

Part 2. (40 items, 10 minutes.) A test of the fundamentals of Spanish grammar.

Part 3. (40 items, 10 minutes.) A test of verb forms and usages.

Part 4. (20 items, 15 minutes.) A measure of Spanish reading comprehension employing three graded paragraphs and questions in English.

Mathematics Aptitude, MA–1 (65 items, 40 minutes).

Part 1. (15 items, 5 minutes.) Consists of arithmetic and algebraic number series similar to those commonly found in intelligence tests.

Part 2. (15 items, 10 minutes.) Primarily a test of constructive imagination. Solution of the problems depends upon the student's ability to visualize geometric figures and to see the relations involved.

Part 3. (20 items, 10 minutes.) This is a test of logic. It measures ability to symbolize and to comprehend abstract relations.

Part 4. (15 items, 15 minutes.) A measure of mathematical reading comprehension. The material (calculus) is unfamiliar to the student, and correct answers call for a grasp of relations and principles.

Mathematics Training, MT–1 (95 items, 40 minutes).

Part 1. (20 items, 10 minutes.) A test of the fundamentals of arithmetic, each item representing a different small skill.

Part 2. (20 items, 10 minutes.) Covers frequently encountered operations in formal algebra.

Part 3. (40 items, 10 minutes.) Basic information in geometry, together with operations which often require that the student draw a figure to obtain the correct solution.

Part 4. (15 items, 10 minutes.) Algebraic reasoning problems in which mechanical computation is reduced to a minimum.

Physics Aptitude, PA–1 (125 items, 45 minutes).

Part 1. (25 items, 13 minutes.) A test of the arithmetical relations in elementary physics.

Part 2. (30 items, 15 minutes.) Paragraphs representing college textbook material in physics are followed by a series of questions which test the student's grasp of the material.

Part 3. (20 items, 10 minutes.) A test comprising number series completion and symbolic logic.

Part 4. (50 items, 7 minutes.) A test of interest in physics as determined from the student's fund of common knowledge of the subject.

Physics Training, PT–1 (125 items, 43 minutes).

Part 1. (40 items, 10 minutes.) A completion test of fundamental information in physics.

Part 2. (50 items, 8 minutes.) A true-false test of additional fundamental information and principles in physics.

Part 3. (20 items, 8 minutes.) Comprises the completion of physical equations and a test of knowledge of important principles.

Part 4. (15 items, 17 minutes.) A measure of the student's ability to solve fundamental problems. Arithmetical computation has been reduced to a minimum.

TABLE 2

FREQUENCY DISTRIBUTIONS OF SCORES IN IOWA PLACEMENT EXAMINATIONS

(The figures in the columns headed *F* indicate the numbers of students whose scores fell within the corresponding score groups in the adjacent columns. The letter *N* signifies the total number of cases.)

Chemistry Aptitude		Chemistry Training		English Aptitude		English Training	
Scores	F	Scores	F	Scores	F	Scores	F
0–2	5	0–9	35	3–7	2	0–9	10
3–7	22	10–19	79	8–12	15	10–19	41
8–12	54	20–29	117	13–17	69	20–29	96
13–17	119	30–39	123	18–22	243	30–39	300
18–22	206	40–49	167	23–27	563	40–49	454
23–27	249	50–59	186	28–32	1,011	50–59	606
28–32	380	60–69	167	33–37	1,526	60–69	602
33–37	421	70–79	187	38–42	1,684	70–79	666
38–42	485	80–89	166	43–47	1,599	80–89	667
43–47	525	90–99	139	48–52	1,118	90–99	667
48–52	449	100–109	116	53–57	570	100–109	659
53–57	519	110–119	88	58–62	171	110–119	655
58–62	408	120–129	61	63–67	12	120–129	596
63–67	483	130–139	42			130–139	479
68–72	407	140–149	22			140–149	408
73–77	335	150–159	18			150–159	302
78–82	303	160–169	2			160–169	199
83–87	229	170–179	1			170–179	107
88–92	164					180–189	44
93–97	91					190–199	7
98–102	54					200–209	1
103–107	6						
108–112	2						
113–117	1						
N = 5,917		N = 1,716		N = 8,583		N = 7,566	

TABLE 2 (*Continued*)

Mathematics Aptitude		Mathematics Training		Physics Aptitude		Physics Training	
Scores	F	Scores	F	Scores	F	Scores	F
0–2	21	0–2	11	20–29	4	0–9	26
3–7	155	3–7	71	30–39	7	10–19	38
8–12	412	8–12	152	40–49	27	20–29	75
13–17	734	13–17	282	50–59	52	30–39	93
18–22	787	18–22	415	60–69	116	40–49	130
23–27	915	23–27	589	70–79	150	50–59	147
28–32	837	28–32	613	80–89	256	60–69	137
33–37	665	33–37	610	90–99	266	70–79	142
38–42	446	38–42	525	100–109	324	80–89	134
43–47	266	43–47	467	110–119	372	90–99	118
48–52	148	48–52	326	120–129	397	100–109	98
53–57	60	53–57	216	130–139	468	110–119	60
58–62	13	58–62	112	140–149	382	120–129	37
63–67	1	63–67	41	150–159	245	130–139	24
		68–72	7	160–169	58	140–149	11
				170–179	2	150–159	4
N = 5,460		N = 4,437		N = 3,126		N = 1,274	

TABLE 2 (*Continued*)

Foreign Language Aptitude		French Training		Spanish Training	
Scores	F	Scores	F	Scores	F
0–9	2	0–9	1	3–7	2
10–19	5	10–19	20	8–12	0
20–29	49	20–29	44	13–17	10
30–39	82	30–39	91	18–22	14
40–49	141	40–49	71	23–27	24
50–59	188	50–59	85	28–32	30
60–69	240	60–69	90	33–37	45
70–79	255	70–79	69	38–42	44
80–89	215	80–89	44	43–47	25
90–99	211	90–99	45	48–52	30
100–109	152	100–109	34	53–57	19
110–119	147	110–119	29	58–62	17
120–129	67	120–129	26	63–67	14
130–139	33	130–139	14	68–72	10
140–149	3	140–149	13	73–77	10
		150–159	1	78–82	7
				83–87	0
				88–92	2
				93–97	0
				98–102	3
N = 1,790		N = 677		N = 306	

TABLE 3

GRADES ACHIEVED IN FRESHMAN SUBJECTS BY STUDENTS PLACING IN EACH FOURTH OF THE GROUP IN PLACEMENT EXAMINATIONS SCORES

(All figures given in the table are percentages)

Chemistry Aptitude + Chemistry Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	67	33	100	0
2	35	51	86	14
3	24	39	63	37
4	2	45	47	53

English Aptitude + English Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	50	42	92	8
2	37	48	85	15
3	24	59	83	17
4	8	58	66	34

Foreign Language Aptitude + French Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	55	45	100	0
2	25	60	85	15
3	14	67	81	19
4	31	38	69	31

Mathematics Aptitude + Mathematics Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	51	44	95	5
2	29	61	90	10
3	10	76	86	14
4	1	59	60	40

Chemistry Aptitude

Quarter	A, B	C, D	Total Pass	Non-Pass
1	51	45	96	4
2	30	56	86	14
3	22	54	76	24
4	10	55	65	35

TABLE 3. *Continued*

Chemistry Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	66	33	99	1
2	31	62	93	7
3	23	50	73	27
4	20	52	72	28

English Aptitude

Quarter	A, B	C, D	Total Pass	Non-Pass
1	44	46	90	10
2	25	59	84	16
3	16	62	78	22
4	8	55	63	37

English Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	53	43	96	4
2	29	60	89	11
3	17	63	80	10
4	4	53	57	43

Foreign Language Aptitude

Quarter	A, B	C, D	Total Pass	Non-Pass
1	55	35	90	10
2	29	59	88	12
3	25	50	75	25
4	19	44	63	37

French Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	48	52	100	0
2	34	52	86	14
3	21	68	89	11
4	38	33	71	29

TABLE 3. *Continued*

Mathematics Aptitude

Quarter	A, B	C, D	Total Pass	Non-Pass
1	47	48	95	5
2	27	55	82	18
3	11	63	74	26
4	4	53	57	43

Mathematics Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	50	44	94	6
2	29	59	88	12
3	12	61	73	27
4	5	50	55	45

Physics Aptitude

Quarter	A, B	C, D	Total Pass	Non-Pass
1	49	49	98	2
2	16	68	84	16
3	10	68	78	22
4	16	44	60	40

Physics Training

Quarter	A, B	C, D	Total Pass	Non-Pass
1	32	65	97	3
2	6	78	84	16
3	3	65	68	32
4	0	42	42	58

TABLE 4

PREDICTION BY INTELLIGENCE TESTS OF FIRST SEMESTER GRADE *AVERAGES* (ALL SUBJECTS) IN COLLEGE

Name of Test	*r*	Source
Army Alpha	.45	Stone (1922)
Army Alpha	.44	Stone (1922)
Army Alpha	.33	Stone (1922)
Army Alpha	.50	Stone (1922)
Army Alpha	.41	De Camp (1921)
Army Alpha	.49	Stoddard (1925)
Army Alpha	.44	MacPhail (1924)
Army Alpha	.45	Colvin (1919)
Thorndike I–III	.60	Thorndike (1922)
Thorndike I	.47	Thorndike (1922)
Thorndike II	.45	Thorndike (1922)
Thorndike I–III	.51	Wood (1923)
Thorndike	.53	MacPhail (1924)
Thorndike	.41	MacPhail (1924)
Thorndike	.41	MacPhail (1924)
Thorndike	.41	MacPhail (1924)
Council on Education	.62	Stoddard (1925)
Council on Education	.54	Thurstone (1925)
Thurstone	.13	Hoke (1922)
Thurstone	.29	Thurstone (1922)
Minnesota	.63	Johnston (1924)
Terman Group	.48	Hoke (1922)
Brown University	.46	MacPhail (1924)
Brown University	.38	MacPhail (1924)
Brown University	.39	MacPhail (1924)
Brown University	.37	MacPhail (1924)
University of Texas	.49	Perrin (1924)
Iowa Placement Examinations	.65 to .75	Stoddard (1926)

PREDICTION BY INTELLIGENCE TESTS OF FIRST SEMESTER GRADES IN SPECIFIC SUBJECTS IN COLLEGE

Name of Test	*r*	Source
University of Texas (Chemistry)	.30	Perrin (1924)
Thorndike I (Chemistry)	.27	Stoddard (1925)
Thorndike I (Chemistry)	.41	Stoddard (1925)
University of Texas (English)	.54	Perrin (1924)
Thorndike I (English)	.42	Stoddard (1925)
Thorndike I (English)	.36	Stoddard (1925)
University of Texas (Mathematics)	.36	Perrin (1924)
Thorndike I (Mathematics)	.23	Stoddard (1925)

TABLE 4. *Continued*

Thorndike I (Mathematics)	.17	Stoddard (1925)
University of Texas (Physics)	.31	Perrin (1924)
University of Texas (Romance Language)	.41	Perrin (1924)
Thorndike I (Romance Language)	.25	Stoddard (1925)
Thorndike I (Romance Language)	.18	Stoddard (1925)
Iowa Placement Examinations:		
Chemistry Aptitude	.48	
Chemistry Training	.52	
Chemistry Aptitude plus Chemistry Training	.52	
English Aptitude	.46	
English Training	.54	
English Aptitude plus English Training	.52	
Foreign Language Aptitude	.52	
French Training	.56	
Spanish Training	.53	
Mathematics Aptitude	.46	
Mathematics Training	.51	
Mathematics Aptitude plus Mathematics Training	.51	
Physics Aptitude	.47	
Physics Training	.61	

TABLE 5

RANGE OF SCORES IN PLACEMENT EXAMINATIONS REPORTED BY COLLEGES ADMINISTERING THE EXAMINATIONS TO ENGINEERING STUDENTS

CHEMISTRY APTITUDE, CA–1, REVISED

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
U. of California	October	640	65.42	67.22	78.16	54.08
Case School of Applied Science	September 23	182	73.74	76.59	84.82	64.41
U. of Cincinnati	November 9	76	39.08	40.28	45.18	34.33
U. of Iowa	September	356	47.46	46.79	58.59	34.92
Kansas State Agric. College	October 1	85	59.78	60.46	71.38	44.75
U. of Minnesota	September 26	335	67.42	68.58	78.94	56.58
Missouri School of Mines	September 18	124	58.87	60.92	69.17	48.06
Montana State College	September 24	116	64.48	64.00	73.13	55.58
U. of N. Carolina	October 19	70	63.00	64.64	76.72	48.33
U. of Oregon	October 9	189	55.10	53.38	69.66	43.01
Rutgers Univ.	October 31	65	77.31	79.46	87.84	67.66
U. of Washington	October 2	144	70.28	71.20	85.50	60.40

TABLE 5. *Continued*

CHEMISTRY TRAINING, CT–1, REVISED

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
Poly. Inst. of Brooklyn....	September 21	61	84.50	79.08	99.19	64.14
Case School of Applied Science...............	September 23	182	89.28	89.96	114.50	63.11
U. of Cincinnati..........	November 9	77	94.36	99.15	119.15	79.05
U. of Iowa..............	September	77	54.73	49.00	69.25	37.19
Kansas State Agric. College..................	October 8	88	44.39	39.05	56.17	28.59
U. of Minnesota..........	September 26	337	65.45	62.34	89.40	38.11
Montana State College ...	September 25	66	47.05	45.42	54.75	37.19
U. of N. Carolina.........	October 19	30	66.50	65.00	83.30	50.00
Rutgers Univ............	October 30	67	90.32	94.50	116.00	82.67
U. of Washington........	October 2	142	69.71	73.80	94.30	39.00

ENGLISH APTITUDE, EA–1, REVISED

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
U. of Arkansas...........	September	95	42.21	42.00	48.58	35.65
Poly. Inst. of Brooklyn....	September 24	90	37.22	38.03	44.33	30.00
Case School of Applied Science...............	September 23	180	39.89	41.37	47.13	34.11
U. of Iowa..............	September	1,030	38.25	38.09	44.85	31.51
Kansas State Agric. College..................	October 1	90	33.89	36.25	43.75	26.25
U. of Minnesota..........	September 28	332	41.34	41.63	47.58	35.69
Missouri School of Mines..	September 25	119	44.75	44.93	50.06	39.58
U. of Nebraska..........	October	200	37.72	38.01	44.25	32.50
U. of N. Carolina........	October 27	71	33.67	32.09	38.28	26.09
Rutgers Univ............	November 4	74	46.28	47.93	51.96	40.56
Univ. of Virginia.........	October 30	29	39.31	40.75	46.13	33.38
Washington & Lee........	October 9	29	37.09	37.00	44.25	30.67

ENGLISH TRAINING, ET–1, REVISED

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
U. of Arkansas...........	September	94	75.99	71.64	108.25	52.00
Poly. Inst. of Brooklyn....	September 24	90	80.83	81.81	105.13	57.00
Case School of Applied Science...............	September 24	184	93.09	92.98	116.17	71.00
U. of Colorado...........	October 15	189	90.00	90.80	110.96	66.71
U. of Iowa..............	September	1,021	87.46	86.04	109.91	61.89
Kansas State Agric. College..................	October 8	86	69.38	65.50	82.00	52.72
U. of Minnesota..........	September 28	336	94.44	92.74	119.50	71.08
Missouri School of Mines..	September 29	117	79.97	80.75	103.82	54.33
U. of Nebraska..........	October	200	86.30	81.32	107.36	53.59
U. of N. Carolina.........	September 15	64	65.59	59.50	84.50	39.50
Rutgers Univ............	November 2	75	108.90	109.95	126.38	90.44
Washington & Lee........	October 12	28	79.75	79.10	103.83	57.17

TABLE 5. *Continued*

MATHEMATICS APTITUDE, MA–1, REVISED

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
U. of Arkansas	September	107	25.57	23.77	33.58	16.44
Poly. Inst. of Brooklyn	September	90	30.28	31.67	38.44	22.27
Case School of Applied Science	September 23	176	29.38	29.75	36.73	22.86
U. of Cincinnati	November 9	77	33.96	35.00	42.81	26.41
Kansas State Agric. College	October 1	91	23.47	22.67	30.67	15.24
Michigan State College	September 17	148	28.07	28.30	34.73	19.71
U. of Minnesota	September 26	333	28.63	28.89	35.81	21.03
Missouri School of Mines	September 26	127	29.73	29.66	36.51	23.05
U. of Nebraska	November 21	160	30.32	28.97	38.67	21.19
U. of N. Carolina	October 19	70	20.71	19.16	25.50	11.92
Purdue University	October 23	100	28.65	28.25	35.36	21.59
Rutgers Univ	October 31	70	34.21	33.50	42.08	27.67
Stevens Inst	October 22	146	38.70	39.36	45.80	31.38
Tufts College	November 11	89	27.87	37.27	39.01	26.85
U. of Virginia	October 30	29	28.62	27.08	35.42	19.56
U. of Washington	October 1	157	29.17	29.21	37.30	18.70
Washington & Lee	October 5	29	26.57	28.00	33.28	19.60
U. of Wisconsin	October 20	249	30.62	30.39	40.04	21.47

MATHEMATICS TRAINING, MT–1, REVISED

U. of Arkansas	September	107	30.08	28.61	38.25	21.38
Poly. Inst. of Brooklyn	September 30	95	39.79	41.11	47.66	29.38
Case School of Applied Science	September 25	186	40.05	40.07	47.25	33.20
U. of Cincinnati	November 9	82	45.00	46.67	48.55	37.92
U. of Colorado	October 22	185	41.11	41.57	49.82	33.06
U. of Iowa	September	302	30.60	30.41	37.07	23.15
Kansas State Agric. College	October 8	95	29.58	31.72	37.19	21.12
Michigan State College	September 17	149	33.91	33.53	41.52	26.07
U. of Minnesota	September 26	329	32.75	33.04	40.50	24.40
Missouri School of Mines	September 25	126	37.90	38.04	44.21	30.47
U. of Nebraska	November 21	182	41.18	41.37	49.20	33.20
Purdue University	October 2	100	37.55	36.62	46.62	29.06
Rutgers Univ	October 31	71	50.21	51.47	57.25	43.25
U. of N. Carolina	October 31	76	25.20	24.08	31.25	17.05
Stevens Inst. Tech	October 8	146	50.51	51.50	57.00	44.06
Tufts College	November 11	84	37.32	42.00	50.50	33.65
U. of Virginia	October 30	29	37.24	39.29	44.79	26.25
U. of Washington	October 1	166	36.45	36.60	45.40	27.60
Washington & Lee	October 7	29	33.64	35.25	40.33	28.75
U. of Wisconsin	October 22	250	40.40	39.85	48.75	32.76

TABLE 5. *Continued*

PHYSICS APTITUDE, PA–1

Name of College	Date Given	Number	Mean	Median	Upper Quartile	Lower Quartile
Poly. Inst. of Brooklyn....	September 29	95	121.55	124.81	140.13	104.73
Carnegie Institute........	September 21	193	143.01	142.34	148.89	130.97
U. of Colorado...........	October 29	184	123.03	126.91	140.19	108.07
Kansas State Agric. College..................	October 1	82	105.96	108.07	126.32	90.06
U. of Nebraska..........	November 28	153	128.09	138.65	142.75	114.13
Penn. State College.......	October	93	117.62			
Purdue Univ.............	April	533	134.25	136.56	146.79	124.31
U. of Pittsburgh.........	September 23	47	105.35	118.86	126.09	85.00
Rutgers Univ............	November 2	62	138.53	140.06	148.67	129.83
Stevens Inst. Tech........	October 21	147	137.02	139.37	148.56	129.70
U. of Washington........	October 2	126	117.99	121.50	134.30	102.80

PHYSICS TRAINING, PT–1

Poly. Inst. of Brooklyn....	October 1	97	68.73	69.08	88.64	49.69
Carnegie Inst............	September 22	193	91.60	91.09	113.02	72.65
U. of Iowa..............	September	154	55.36	54.17	70.00	38.18
Kansas State Agric. College..................	October 8	79	60.43	56.85	79.78	39.19
U. of Nebraska..........	November 28	155	66.69	63.30	84.03	46.52
Penn. State College.......	October	86	54.62	50.93	72.68	36.32
U. of Pittsburgh.........	September 23	43	29.62	36.00	47.56	25.25
Rutgers Univ............	November 2	62	78.21	75.50	95.75	58.00
Stevens Inst. Tech........	October 7	146	86.08	88.39	103.88	67.25
U. of Washington........	October 2	143	68.14	66.80	87.10	47.40
U. of Washington........		77	92.81	97.80	108.80	74.50

TABLE 6

COMPARISON OF RELIABILITY COEFFICIENTS FOR FORTY MINUTES' AND FOR EIGHTY MINUTES' TESTING TIME

Name of Examination	Reliability 40 Minutes' Testing	Reliability 80 Minutes' Testing
Chemistry Aptitude	.88	.94
Chemistry Training	.93	.96
English Aptitude	.82	.90
English Training	.90	.95
Foreign Language Aptitude	.97	.98
French Training	.93	.96
Spanish Training	.82	.90
Mathematics Aptitude	.86	.92
Mathematics Training	.88	.94
Physics Training	.85	.92

TABLE 7

NORMS, IOWA PLACEMENT EXAMINATIONS, SERIES 1, REVISED, FORM A

	CA	CT	EA	ET	FA	MA	MT	PA	PT
Number of Cases	5,917	1,726	8,583	7,566	1,790	5,460	4,437	3,126	1,274
Mean	53	70	40	96	78	26	34	116	70
Median	53	68	40	95	78	26	33	119	69
Upper Quartile	69	94	47	123	97	34	43	137	92
Lower Quartile	38	44	33	66	59	18	24	96	46
Standard Deviation	21	34	10	38	27	11	13	28	31
Percentiles									
99	98	152	60	173	138	54	63	164	142
90	82	116	52	147	114	42	51	149	111
80	73	100	48	130	102	36	46	141	98
70	66	88	45	118	93	32	42	134	87
60	59	78	43	106	85	29	37	127	78
50	53	68	40	95	78	26	33	119	69
40	47	59	38	83	73	23	30	111	60
30	41	49	35	72	62	20	26	101	51
20	34	39	32	60	54	16	22	90	41
10	26	25	27	46	42	12	16	77	28
1	10	2	17	21	22	4	5	47	2

Abridged norms for French Training and Spanish Training, on a smaller number of cases, are given below.

	FT	ST
Number of Cases	677	606
Mean	60	42
Median	57	40
Upper Quartile	75	51
Lower Quartile	41	31
Standard Deviation	25	16

Norms. Composite scores for comparative purposes.

Mean. Arithmetic mean, or average.

Median. The middle score, or score exceeded by one half of the cases.

Upper Quartile. The score *above* which are one quarter of the group tested.

Lower Quartile. The score *below* which are one quarter of the group tested.

Percentile. The *p* percentile is the score *below* which are *p* per cent of the cases. The fiftieth percentile is the median.

Standard Deviation. The square root of the mean of the squares of deviations from the arithmetic mean of the scores.

ANNOTATED BIBLIOGRAPHY

(1) Cornog, J., and Stoddard, G. D. ''Predicting Performance in Chemistry.'' *Journal of Chemical Education,* Vol II, No. 8 (August, 1925), pages 701–708.

This article describes the Placement Examinations in Chemistry from the following standpoints: Necessity for the examinations; the nature of the examinations; the philosophy and content of the aptitude and training examinations; data and conclusions; and a theoretical discussion of the values and uses of these tests.

(2) Cornog, J., and Stoddard, G. D. ''Predicting Performance in Chemistry, II.'' *Journal of Chemical Education,* Vol. III, No. 12 (December, 1926), pages 1408–1415.

This article gives tentative answers to the following questions: How accurately are students placed by the Iowa Placement Examinations in Chemistry Aptitude and Chemistry Training? Are there notable differences in the quality of institutional groups of students taking freshman Chemistry? How much and what kind of Chemistry is retained by Freshmen who have had high school Chemistry?

(3) Langlie, T. A. ''Analysis of the Iowa Placement Tests.'' *Journal of Applied Psychology,* Vol. X, No. 3 (September, 1926). pages 303–314.

This study consists of a critical analysis of the behavior of the Placement Examinations in English, Mathematics, and Chemistry. The data were obtained at the University of Minnesota. All tests were in the *tentative* series of Placement Examinations. Below are given Langlie's conclusions. That these findings are subject to interpretations differing from those of Langlie has been pointed out by Stoddard (18).

(*a*) "The tests under consideration do differentiate fairly well, except the Chemistry Aptitude test with its coefficient of variability .09." (This coefficient was raised to .22 in the revised series of 1925.)

(*b*) "Each test is dependent to a fair degree upon general intelligence, particularly the aptitude tests."

(*c*) "A particular aptitude is dependent upon training in that particular line."

(*d*) "Mathematics Training and Chemistry Training as measured by these tests have considerable in common, presumably training in mathematics."

(*e*) "The training tests in Mathematics and Chemistry are different from intelligence and aptitude tests."

(*f*) "Finally, we may conclude that the factors measured by these tests are: general intelligence, training in particular subjects, and mathematical aptitude."

(4) LANGLIE, T. A. "The Administration of Placement Examinations." *School and Society,* Vol. XXIV, No. 620 (November 13, 1926), pages 619–620.

This article compares the examinations in English, Mathematics and Chemistry used at the University of Minnesota in 1924 and 1925, and indicates superiority of the 1925 edition in measuring individual differences among college freshmen. Correlations are given which indicate that the superior examinations of 1925 did not in the case of Mathematics Training and Chemistry Training produce higher relationships between test performance and semester grades. Langlie attributes this to the fact that the examinations were given earlier in the semester of 1925. He proposes that these examinations should be given two or three weeks after the opening of the semester in order to permit a brief review of the subject matter on the part of the students.

(5) LANGLIE, T. A. "The Iowa Placement Examinations at the University of Minnesota." *Journal of Engineering Education,* Vol. XVII, No. 9 (May, 1927), pages 842–860.

This report utilizes data obtained at the University of Minnesota in 1924, 1925 and 1926 for the Training and Aptitude Examinations in English, Chemistry and Mathematics. Below are the questions emphasized in the study together with the conclusions reached.

(1) ''Do the Placement tests adequately reveal individual differences among college Freshmen?''—''The Placement tests reveal individual differences to an unusually high degree, coefficient of variability being above .30 for all but two tests, E.A., .18, and C.A., .22. The 1925 edition is greatly improved over the 1924 edition in this respect.''

(2) ''Do the Placement tests throw light on the adequacy of the present classification of students in the departments of Mathematics and Chemistry?''—''As a check on the classification of students in the mathematics and chemistry departments, the training tests are more effective than are the aptitude tests. The different courses in these departments are composed of fairly homogeneous groups of students, each group being different from the other as far as these special abilities are concerned.''

(3) ''Could the tests be used for sectioning classes on the basis of ability in English, Mathematics, and Chemistry? If so, should the tests be given before registration or after brief review in each subject?''—''Sectioning classes on the basis of ability could be done fairly successfully with scores on the aptitude and training tests as guides. English classes in particular could be sectioned on the basis of ability with a minimum of error. More than 33 per cent of the grades of English classes (1925) were predicted exactly, this with scores on the English training test alone ($r = .63$). Sectioning in the mathematics and chemistry departments probably could have been done with almost equal accuracy if the training tests had been administered at a later date, when the students would have had an opportunity for a short review.''

(4) ''Do the tests yield valuable information for the use of the Dean's office, Student Work Committees, and Advisers?''—''The placement tests yield valuable information for administrative purposes such as personnel work, students' work committees, and advisory work. Encouragement and discouragement of continued study at the University can be done much more accurately when test scores are used as a guide than when scholarship and impressions alone are considered.''

(6) LEMON, A. C. ''An Experimental Study of Guidance and Placement of Freshmen in the Lowest Decile of the Iowa Qualifying Examination, 1925.'' *University of Iowa Studies in Education*, Vol. III, No. 8 (February 1, 1927); 135 pages.

This study reports the carrying out of a rigorous experiment on the effectiveness of individual student analysis and remedial instruction. An experimental and a control group were carefully matched on the basis of intelligence and Placement Examinations, and various environmental conditions. For a period of one semester members of the experimental group were diagnosed psychologically and educationally and shown how to improve in reading ability, methods of study, interest-taking, etc.

A striking improvement was obtained for the experimental group in average scholarship and in the number surviving the first and second semesters. Thus in the control group only 17 (out of 53) were eligible for registration at the beginning of the Sophomore year, while in the experimental group 32 (out of 53) were eligible. The study includes an analysis of the remedial technics found to be effective and sets up a plan of adjustment which, it is believed, would reduce significantly the high percentage of elimination among beginning college students.

(7) REMMERS, H. H. ''A Diagnostic and Remedial Study of Potentially and Actually Failing Students at Purdue University.'' *Purdue University Studies in Higher Education IX,* May, 1928; 164 pages.

''This study deals with approximately the lower twenty-five per cent of the freshmen at Purdue University as measured by various tests. The problem attacked is that of the possibility of improving scholastic achievement by means of directed study. The methods used are as follows: (1) a diagnostic investigation in terms of tests, interviews, and the collation of various kinds of sociological, familial, and educational data; (2) a division of the students into two comparable groups with special treatment of one of these by means of directed study especially in English and mathematics, the other group serving as a control group; (3) the second semester those freshmen not in the lower quartile on entrance tests who failed to carry twelve semester hours of passing work (*i.e.,* probationers) were also given special treatment. The remedial aspects of the study produced results which indicate that the procedure employed held seventy per cent of the experimental group as against fifty-two per cent of the control group in the University throughout the year. The mean differences are in all cases slight, but usually in favor of the experimental group. The study indicates the need for better educational and vocational counseling in the secondary schools than now obtains. No unequivocal results were obtained in the case of the probationers.''

(8) RUCH, G. M., AND STODDARD, G. D. *Tests and Measurements in High School Instruction.* World Book Company, Yonkers-on-Hudson, New York, 1927. 382 pages.

''In part one the following major uses of standardized measures are classified and discussed: (1) Supervision and administration of instruction; (2) diagnosis of special difficulties; (3) grading, promotions, and sectioning of classes; (4) research purposes; (5) motivation of learning. In part two appears a

full description of available high school tests, classified by subjects. A statement is made concerning what each test measures, how to administer and score, how to interpret and utilize the results, the establishment of norms, and the validity and reliability of the tests. Part three covers informal objective examination methods as they may be successfully applied to high school instruction. Part four presents the fundamental principles underlying the construction of educational and mental tests. The sequence of steps in the production of typical tests is developed in some detail. The important steps in the construction of tests and scales are covered: validation, breaking the test items into equivalent forms, derivation of norms, determination of reliability, and perfecting the administration of the test.''

(9) SEASHORE, C. E. ''Sectioning on the Basis of Ability.'' *Bulletin of American Association of University Professors,* Vol. IX, No. 6 (October, 1923), pages 9–24.

This report establishes a strong logical case for the sectioning of classes both in principle and practice. Various objections to the plan are met by the writer and some preliminary comments from teachers are appended.

(10) SEASHORE, C. E. ''Comments on the Plan for Sectioning Classes on the Basis of Ability.'' *School and Society,* Vol. XVI, No. 140 (November 4, 1922), page 514 ff.

This article consists of a series of comments from nineteen colleges and universities on the plan of sectioning previously proposed by the writer. Institutions which have put the plan into practice reported favorably on it.

(11) SEASHORE, C. E. ''College Placement Examinations.'' *School and Society,* Vol. XX, No. 515 (November 8, 1924), pages 575–577.

This constitutes the first published article describing briefly the nature and purpose of the trial edition of the Iowa Placement Examinations. The essential guiding principles are set forth.

(12) SEASHORE, C. E. ''The Placement Examinations as a Means for the Early Discovery and Motivation of the Future Scholar.'' *National Research Council Bulletin,* reprinting an address of October 29, 1925.

The author sets up ''fourteen points'' believed essential in making the proper educational recognition of individual differences among students. The Placement Examination procedure is considered of prime importance among these projects.

(13) SEASHORE, C. E. ''Learning and Living in College.'' *University of Iowa Studies,* Vol. II, No. 1 (March 1, 1927); 124 pages.

The writer sets up the educational goal, ''to keep each individual busy at his highest natural level of successful achievement,'' and organizes the discussion about certain major procedures designed to promote this end. Among these are selection of students, Placement Examinations, Freshman Week, individualization of recitation and laboratory, sectioning of classes, the project method, the Junior College, and honors and awards. For the most part the elaboration of the principles underlying these projects is accompanied by an account of the way they have worked out under actual conditions at various institutions.

(14) STODDARD, G. D. ''Iowa Placement Examinations.'' JOURNAL OF ENGINEERING EDUCATION, Vol. XVI, No. 1 (September, 1925).

A brief summary of the results obtained with the tentative edition.

(15) STODDARD, G. D. ''Iowa Placement Examinations, Fall of 1925, Preliminary Report.'' JOURNAL OF ENGINEERING EDUCATION, Vol. XVI, No. 7 (March, 1926), pages 475–483.

This report consists of a series of tables giving for each particular college and for each Iowa Placement Examination the number of students taking the test, and the mean, median, upper quartile, and lower quartile obtained.

(16) STODDARD, G. D. ''Iowa Placement Examinations.'' *University of Iowa Studies in Education,* Vol. III, No. 2 (August 15, 1925); 103 pages.

This study comprises the first complete account of the Iowa Placement Examinations (tentative edition). It describes the experimental work undertaken by a group of men at the University of Iowa in cooperation with the Society for the Promotion of Engineering Education. Ten thousand cases are reported. The chief topic headings are: The need for the investigation; a survey of similar investigations; the function of Iowa Placement Examinations; a description of the content of the examinations; a statistical study of the examinations; the method of revising the examinations; various types of norms; and the effectiveness of the examinations in predicting scholastic success in a particular college subject. Through the technique of partial and multiple correlation the superiority of Placement Examinations over intelligence tests in predicting performance is indicated. The utility of the distinction between aptitude and training is brought out.

(17) STODDARD, G. D. ''Iowa Placement Examinations.'' *School and Society,* Vol. XXIV, No. 607 (August 14, 1926), pages 212–216.

A general account of the nature and purpose of the examinations. The usefulness of the examinations in various types of student personnel work is pointed out.

(18) STODDARD, G. D. ''Iowa Placement Examinations—A New Departure in Mental Measurement.'' *Psychological Monograph. University of Iowa Studies in Psychology,* Vol. XII.

A critical analysis of theoretical points involved in measurements by Placement Examinations.

(19) THARP, JAMES B. ''Sectioning Classes in Romance Languages.'' *Modern Language Journal,* Vol. XII, No. 2 (November, 1927), pages 95–114.

This study describes the carrying through of a definite experiment in French instruction at the University of Illinois. Iowa Placement Examinations proved effective in placing students in their proper level of ability, as shown by the marks received at the end of the semester. The conclusions definitely favor the plan of class sectioning.

(20) YOUNG, C. E., AND VAN DER BEKE, G. E. ''An Experiment in First Year French.'' *Modern Language Journal,* Vol. XI, No. 1 (October, 1926), pages 25–31.

''This experiment was conducted on the assumption that students will make more rapid progress in reading ability in the long run if at the beginning of the course they are tested for their knowledge of certain important items, and if steps are taken to remedy the defects of the individual student.'' The Placement Examination, French Training, was employed and a series of remedial drills given to overcome weaknesses in student preparation. At the end of the semester the experimental group had outdistanced six other groups which were taught without preliminary testing.

More recently further experiments at the University of Iowa not reported in this article have corroborated these preliminary findings as to the value of early knowledge of the aptitude and training of beginning college students.

BULLETIN NUMBER 16
OF THE
INVESTIGATION OF ENGINEERING EDUCATION

A COMPARATIVE STUDY OF ENGINEERING EDUCATION IN THE UNITED STATES AND IN EUROPE

by

William E. Wickenden,

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FOREWORD

This bulletin presents one of a series of fact-finding studies included in a general investigation concerned with "the objects of engineering education and the fitness of the present-day curriculum" which has been carried out during the years 1924 to 1929 inclusive by the Society for the Promotion of Engineering Education under a grant of funds by the Carnegie Corporation of New York. There is also included considerable material on technical schools giving more intensive forms of training than the usual professional courses in engineering, which was gathered for use in a special investigation in that area.

Both investigations have been conducted under the general direction of the Board of Investigation and Coordination and under the immediate supervision of the Staff, as named elsewhere.

The bulletins are published by the Society through its Board of Investigation and Coordination as the documentation of the investigations, but the responsibility for their contents, for the opinions expressed and for the recommendations made rests in all cases on the authors and editors of the particular material presented. The more general findings and recommendations of the Board, based upon a synthesis of the several studies, are to be published separately.

A COMPARATIVE STUDY OF ENGINEERING EDUCATION IN THE UNITED STATES AND IN EUROPE

By

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INTRODUCTION

Objects and Scope of the Study.—The centenary of technical education in America marks the present decade as a timely occasion for an appraisal of results and a reconsideration of aims and methods. These have been the objects of an extended investigation to which the engineering colleges, the technical schools, the industries, the professional societies of engineers, the United States Bureau of Education and other agencies have contributed a group of important factual and interpretive studies. These unit studies necessarily have dealt with limited aspects of the situation and were made from particular points of view, many of them from within. To round out the data for an adequate appraisal there was an obvious need to survey the situation in a wider perspective and from a more objective viewpoint. The sponsors of the investigation felt that this need could best be met by a comparative study of engineering education in the United States and in a group of leading European countries. As the study progressed it became apparent that the education of engineers as a professional group could not be dealt with effectively apart from the education of the higher and middle ranks of industrial supervisors and technicians. The study was therefore extended to cover both the professional schools of engineering and what are known on the continent of Europe as the "higher technical middle schools." This Bulletin presents both phases of the study. Only incidental reference is made to the training of craftsmen and to pre-industrial training in early adolescence. Secondary education is dealt with in so far as it supplies an essential foundation for higher technical studies. In certain cases a schematic picture of the national scheme of education is included as an aid to orientation.

Terminology.—It is difficult to define the scope of the study and to express its data and findings in terms having a common acceptance. The term ''engineering education'' is loosely used in America and has no direct equivalent in the more precise terminology of continental Europe. The same term is frequently used in England in a more special sense to denote education for the machine industries. Throughout continental Europe ''technical education'' is an inclusive term for the training of all ranks of specialists in industrial and building technology, architecture, agriculture, forestry and, in Germany at least, psycho-technics as well. The continental systems may be divided into three quite distinct categories of technical education, commonly called ''higher,'' ''middle'' and ''lower.'' Our terms ''professional'' and ''vocational'' fit the first and last reasonably well, and it is convenient to borrow the term ''middle'' for the intermediate category, which is less widely recognized in America. It should be pointed out, however, that the French word *professionnel* is practically identical in meaning with our word ''vocational.'' The term ''technical education'' has been given a legal definition in Great Britain which excludes ''teaching the practice of any trade or industry or employment.'' The term ''technology'' is commonly used abroad to denote the practical arts of industry rather than the underlying technical sciences.

Acknowledgments.—The data and observations which form the basis of this study were gathered in part by personal visitation in 1925 and 1928 and in part from publications and correspondence in the interim. So far as is known subsequent changes have not altered the principal features of the pictures here presented. The writer wishes to express his gratitude to the public officials, officers of engineering societies, educators, engineers and industrialists, far too numerous for individual mention, without whose invaluable aid the study could not have been accomplished. He is happy to testify to the cordial interest of the engineers and educators of Europe in the progress of American schools, which has been heightened by the change of America's position from an importer to an exporter of technical products and services.

There is little possibility of direct borrowing from educational systems which have grown out of other economic and cultural conditions. The value of comparative studies, apart from their aid to self-criticism, arises largely from the gain in mutual acquaintance and understanding. Engineering varies in function and practice from nation to nation and the variety of national types is worth preserving as a spur to progress. Its essential genius, however, is universal. As heirs in common to all the arts and sciences engineers have a duty to foster a generous spirit of emulation that may help to lift international competition off a sordid plane. Until recent years America has had the advantage of meeting competion in science and technics largely on her own ground and her own terms, by the simple process of assimilation. Europe has sent us trained men, educational models, professional traditions and the fruits of her research and we have made them our own. We have given in return, but not in equal measure. Henceforth we must balance this account more evenly. While we shall continue to welcome and to assimilate the engineer, the technician and the craftsman of European training, it is plain that we should depend less on this source to fill gaps in our scheme of technical education. The American engineer should be able to meet the world's best in any field on terms of unquestioned equality, both in culture and in technical proficiency.

Technical Education and Economic Well-Being.—These studies will fail of their larger purpose if they do not emphasize the importance of seeing the problem of technical education whole and of bringing some adequate initiative to bear upon it. Experience seems to indicate that it is equally possible to go wrong under a central bureaucracy or by depending entirely on individual and local initiative. France showed remarkable fertility and held undisputed leadership in technical education up to 1850. Then followed forty years of arrested development. The State held an educational monopoly, but took no effective initiative; responsibility was scattered among various bureaus and ministries, each caring for its special needs with little concern for the nation as a whole; the schools were unduly concentrated in Paris; and nearly the whole effort was spent on the training of bureau chiefs and directors of industries, while the subalterns were almost wholly neglected. Local and private enterprise finally came to the rescue, but only after the early supremacy in technical education had been irretrievably lost, with disastrous effect on French industrial development.

Great Britain lost fifty years of her early lead over Germany through ineffectual development of technical education. Before 1880 virtually everything was left to private or local enterprise; few perceived that a specially selected and trained personnel was needed to apply science to industry effectively; nearly a century of effort was concentrated on the incidental teaching of science to workingmen, largely inspired by welfare motives—an admirable thing, in itself, but a wholly inadequate scheme of technical education; meanwhile technical education and research in the universities were almost stifled by lack of support and the backward state of preparatory education.

Nowhere else have technical education and research had so large a share in shaping national destiny as in Germany. Thrown out of the academic institutions through the conservatism of old-school educators, technical education was taken up and fostered by far-seeing statesmen bent on transforming a group of backward agricultural states into a dominant industrial empire. New types of schools, industrial, secondary and professional, had to be created from the ground up. There was an early period of confused effort, but after 1860 it was increasingly evident that while the states and industries were supplying the greater part of the motive power, the technical professions were guiding the movement out of confusion to clearly visualized goals. Today, the chief guiding agency is the *Deutscher Ausschuss für Technisches Schulwesen,* a central representative committee which brings together the technical professions, industries and schools for effective collaboration with the government ministries in the guidance and support of technical education in all its branches.

In the United States we have done parts of the task well, but other parts we have scarcely done at all and no one has seen the task whole. We began with a broad aim "to apply science to the common purposes of life," but there was an early fixation of technical education in one special form—a professional discipline for engineers. Only this one aspect of technical education has been adequately developed, and in the effort to make it comprehensive there has been an inevitable blurring of aims and compromise of standards. Colleges, professional bodies and industries have not agreed upon specifications. The spirit of technical education is individualistic, without an underlying economic and social program to balance the concern for the personal development of the student. Can this laissez-faire policy be trusted as an adequate guide? Not if the experience of more mature nations under more severe economic pressure may be taken as a criterion. It is plain that we can not look to a central government for a national policy and program in technical education. Our national genius in such matters works through voluntary coordination. The next step is to prepare the way for some central representative agency, such as that in Germany, and to awaken the public to the vital part that an adequate and well-proportioned scheme of technical education and research plays in the general economic well-being.

PART I. THE HISTORICAL DEVELOPMENT OF ENGINEERING EDUCATION

There are significant differences of national thinking as to what an engineer is, what are his functions in the social order and how he may best be trained, which can be understood only in the light of their evolutionary development. The character of institutions, like that of persons, is largely conditioned by heredity and early nurture. Fifty years ago C. O. Thompson, the first president of Rose Polytechnic Institute, observed from his studies of the engineering schools of Europe that there had been little change in their essential features after the first ten years of their existence. From that period on their growth was essentially a maturing rather than a formative process. The present study tends to confirm this general law of development.

National Conceptions of Engineering.—The word *engineer* embodies a Latin root *gen* which denotes highly creative attributes. The direct line of derivation may be traced to *ingenium*—natural capacity, talent, capacity for invention—and is closely linked with the words *genius* and *ingenuity.* The continental languages preserve these root values more faithfully than the English, as in the French *ingénieur,* the Spanish *ingeniero,* the Italian *ingegnere* and the German *ingenieur.* All these languages commonly use some variant of the word *machine* where the English employs the word *engine.* By a trick of etymology the words *engineer* and *engine* have become intimately linked in English speech and thinking, so that an engineer is instinctively thought of as one who builds, applies or operates engines, leaving the connotations of creative ingenuity of the Latin root somewhat obscured. This circumstance has colored British usage to a greater degree than American. In the British sense the term engineering is commonly applied to all machine building activities, and the term *engineer* indiscriminately to men engaged [illegible] industries and professional services. The engineer is pre-eminently a professional man of special scientific training in continental Europe. British tradition regards the engineer as a practical builder who has acquired some mastery of the science underlying his art. The method of his scientific formation is incidental, but whatever its extent, he is expected "to go through the mill" of practical apprenticeship. The American conception is less clearly defined, but is intermediate between the British and the continental types.

The Influence of Underlying Traditions.—In origin and historical development British engineering is closely linked with handcraft and continental engineering with formal science. Whereas scientific inquiry, training for practical professions and industrial pursuits were equally cut off during their formative years from the dominant seats of learning in England, the higher schools of the continent became the chief sources of their nurture from the earliest years. These circumstances have directed the main streams of educational activity into widely divergent channels. Motives of individual welfare and traditions which grew up around the pioneers of the industrial revolution led Great Britain to devote her major energies throughout the 19th century to the teaching of science to working men. The need of a specially selected and trained personnel to apply science to industry gained recognition slowly. The chief heritage of the century is a magnificent system of local technical institutions, devoted principally to part-time and evening instruction for industrial employees. The place of technical education and research in the British university system was comparatively small until the last years of the century; since then its development has been greatly accelerated.

The traditional link between engineering and craftsmanship has led Great Britain to preserve in her system of technical education an ideal of "vertical mobility" which is almost wholly lacking in the sharply stratified schemes of the continental countries. France was the first to perceive that the effective application of the technical sciences requires a highly selected and trained personnel and to provide a professional discipline for engineers in schools of the highest rank. France was also first in providing a distinct type of education for industrial supervisors. Germany was conspicuously first to grasp the potentialities of specialized research as the dynamic of technical progress; also the first to provide a universal scheme of vocational education for her youth entering industry in their early years.

Traditional influences have led to an unsymmetrical growth of technical education in America. A century ago the pioneer phase of an effort to promote "the application of science to the common purposes of life" was quickly transmuted into the form of a professional discipline for engineers and assimilated into the newly developing system of university education. Coincident with the railroad there came a demand for engineers versed in the scientific resources of their art. The scattered group of military engineers and self-taught civilians of the earlier period could scarcely be called a professional body. There was nothing to which the English system of pupilage could attach itself and the engineering school arose from simple necessity. The models borrowed from France gave to American engineering education a distinctly professional character and spirit. This early fixation has resulted in a one-sided growth; technical schools have multiplied after the single pattern of the degree-granting college; the systematic training of craftsmen and technicians and of supervisors of industrial production has been largely neglected; we have been tardy in creating an effective group of vocational schools; and the standards of professional "engineering education" have been strained to accommodate forms of training in specialized technology which seem clearly to belong in some other category. European experience indicates that progress to a better rounded system and to higher standards of achievement may be expected only as we define the functions and limit the aims of our schools more precisely and in doing so divide the area of activity among schools of different types and categories, working on different levels of age, previous training and experience, scientific content and specialization, using different educational methods, but all striving to attain the highest degree of excellence.

A. HISTORICAL DEVELOPMENT, FRANCE

The Germinal Period.—The builders of antiquity and the Renaissance were both architects and engineers. The most brilliant examplar of this earlier versatility was probably Leonardo da Vinci. Art and science diverged into separate fields of endeavor so gradually that no time and place can be fixed for the birth of engineering in its modern sense. In all probability the process took place in mediæval France, where the construction of roads, bridges and waterways was a royal concern from the days of Charlemagne. A royal *Corps des Ponts et Chaussées* is known to have existed as early as the 13th century. Charles V (1364–1380) mentions *nos ingénieurs des ponts et chaussées* in a royal ordinance. An episode of the reign of Louis XIV (1642–1715) makes it clear that the engineering profession had begun to develop a consciousness of its own. In his enthusiasm for monumental structures the Grand Monarch commissioned his favorite architect Mansart to build a stone bridge at Moulins on the Allier. Mansart was a master of masonry construction, but he knew nothing of hydraulics and the erosive action of streams. His bridge soon collapsed. The engineers of the period capitalized this setback with a rare sense of publicity and let it be known

> ''that they had at their command an art of construction, applicable to great public works, more learned and more varied in its resources, looking to solidity rather than monumental decoration.''

Creation of the Ecole des Ponts et Chaussées.—Louis XV (1715–1754) undertook to repair the economic structure of France, shattered by the extravagences of his predecessor. His plans called for the construction of a vast system of national highways. The direction of the work was entrusted to an engineer Perronnet who proved to be a man of exceptional genius. Perronnet may be called the father of modern civil engineering and was certainly the father of engineering education. When summoned to Paris in 1747 to become chief engineer of bridges and highways he was charged

> ''with the direction and supervision of surveyors and designers of plans and maps of the roads and highways of the realm and

> of all those who are appointed and nominated to said work; and to instruct the said designers in the sciences and practices needful to fulfilling with competency the different occupations relating to the said bridges and highways.''

Perronnet's commission was the germ of the first engineering school. Hitherto engineers had prepared for the exercise of their art by isolated and unorganized studies and the provincial cities where they were often stationed afforded them scarcely any means of professional improvement. The majority had little or no theoretical equipment—imitation and routine were often their only guides. Perronnet found a complete lack of uniformity in standards and practices, as well as in the routines of field notes, reports and estimates. Forced by circumstances to organize a corps of draftsmen bound by common conventions and norms, Perronnet ingeniously transformed this staff into a veritable school of student engineers. In his orders of Dec. 11, 1747 he directed:

> ''That these employees will be divided into three classes; the first composed of under-inspectors or under-engineers; the second of employees called *élèves;* and the third of young men of less education who are admitted to work in the office as auxiliaries.''
>
> ''That the employees of these three classes not otherwise employed will report to the office of Perronnet daily, Sundays and holidays excepted, from eight to noon and from two to eight.''
>
> ''That exceptional rewards will be given to the three most proficient employees of each class, who are to follow the courses of professors of mathematics and architecture indicated by Perronnet.''
>
> ''That during the summer, the employees are to be distributed among the principal works in progress, to execute maps and plans.''

While the school began to function in 1747 the name *Ecole des Ponts et Chaussées* was not officially bestowed nor the institution legally regularized until 1775. In addition to the external professors provided by Perronnet, he directed the employees of the highest class to act as instructors of their juniors. This scheme of ''mutual instruction'' continued in force until 1799. Otherwise the school retains most of its original characteristics to this day. It is still an appendage of the official *Corps des Ponts et Chaussées;* the program of studies remains three years in length; the regular students rank as state employees; the professors are in part eminent savants and in part leading engineers of the *Corps;* many of the exercises are actual engineering projects; and the summers are occupied by *stages* at important works in progress. This original pattern has left its mark on all engineering education in France.

The Ecole des Mines.—The mineral industries were largely neglected in France until the middle of the 18th century. When miners or metallurgists were needed they were commonly gotten from Germany. Louis XIV sought to develop the mineral resources of France as a means of revenue to the State. At the suggestion of an ambitious mineralogist Sage, the King authorized the creation of a public and gratuitous school of mineralogy, assaying and metallurgy at the Paris mint. This was in 1778. A royal *Bergakademie* had already been established at Freiberg in Saxony in 1765. These two schools had a dominant place in the early training of the mining engineers of Europe and supplied models to the first mining schools of America. When an official *Corps des Ingénieurs des Mines* was created to foster and regulate the mineral industries of France in 1783 the school at the mint became the *Ecole des Mines* with a rôle analagous to that of the *Ecole des Ponts et Chaussées.* The school passed through many vicissitudes, both internal and external, and the Revolution found it but feebly established. The Convention suppressed it in 1802 in order to create two schools in the mineral basins. The Restoration created an *Ecole des Mineurs* at St. Etienne in 1816 and shortly thereafter restored the *Ecole des Mines* at Paris in the sumptuous precincts of the Hotel Vendome, where it remains today. From that stage on its development was notable. A bureau of tests for mineral substances, the forerunner of industrial research laboratories in engineering schools, was established in 1845.

The *Ecole des Mines* supplied much of the inspiration for the School of Mines at Columbia, opened in 1864, through which it has influenced all the mining schools of America. A British mission which studied technical education on the continent in 1873 reported that it possessed ''model laboratories and the most magnificent mineral collection in the world." The *Ecole des Mines* has held consistently to a lofty scientific discipline and has made no effort to simulate industrial operations in its laboratories, holding that the art must be learned where practiced. Practical training has been provided for by placing the students as *stagiares* in the mines during the long vacations.

Ambitious Schemes of the Convention.—At the outbreak of the Revolution the flourishing technical schools for the military and civil functions of the State were threatened with complete disorganization. The students were placed at the disposal of the Minister of War and when their ranks were replenished under the levelling influence of the Convention the new pupils were found to be loyal republicans but otherwise ignorant of the most elementary things of science and mathematics. Lamblardie, Perronnet's successor at *Ponts et Chaussées,* proposed to rectify this situation by creating a great central school for the recruitment of all the technical services of the State, with facilities for a thorough scientific discipline. He confided this idea to Monge, the dominant influence at the school of military engineering, who in turn secured the approval of the Convention. The law of 1794 created an *Ecole des Travaux Publics* to train engineers for all the needs of the army, the public services and private industry. It was a time when men were thinking boldly and easily overlooked elemental limitations. Monge at once began to organize the new institution on an unprecedented scale in the vast premises of the Palais Bourbon. The course was to cover three years and was to comprise both scientific and technical studies. Each "promotion" or annual quota of entering students was to number 400 and to be chosen by competitive examination from the elite of French youth. The school day was to extend from 8 to 2 and from 5 to 8, with the exercises carefully distributed so as to sustain interest and avert fatigue. Ten months of the year were to be given over to teaching, one to examinations and one to vacation. To round out a national scheme of scientific and technical education, the Convention also projected *écoles centrales* in all the provincial capitals. Neither plan succeeded, yet neither was lost. The *Ecole des Travaux Publics* was replaced after a single year by the *Ecole Polytechnique,* of a more limited character, and the *écoles centrales* proved to be too costly and to lack effective bonds with the elementary education of the times. At a later period, in 1829, the basic ideas were reincorporated in the *Ecole Centrale des Arts et Manufactures,* from which a wide influence radiated throughout Europe and America.

The Ecole Polytechnique.—The idea of a central school for all the technical services of industry and the State was soon abandoned. The specialized schools of application were retained and a preparatory institution ''consecrated to a high intellectual and scientific formation'' was created as the source of their recruitment. The revolutionary period was one of extraordinary scientific fecundity in France. The new *Ecole Polytechnique* drew to its staff a brilliant group of creative men and at once became the most renowned center of scientific teaching in the world. The names of Lagrange and LaPlace in mathematics, Prony in mechanics, Monge and Hachette in descriptive geometry and stereotomy, Delorme and Baltard in architecture, Fourcroy, Vauquelin, Berthollet, Chaptal and Guyton de Mourveau in chemistry adorn its early annals. Monge was the dominating figure. His enthusiasm for descriptive geometry has left its imprint on all engineering curricula to this day. He brought over from the *Ecole de Génie* the method of admission by *concours,* a severe competitive examination based chiefly on mathematics, which still remains the most distinctive feature of French technical education. The examiners were instructed ''to select those who know the best, rather than those who know the most.'' Napoleon gave the school a military regime in 1804 and it has contributed both directly and through its graduates to the most brilliant chapters in French military history. Since its foundation the *Polytechnique* has been the most eagerly sought after and the most difficult of access of all the schools of France and probably of the world, both because of the prestige of its teaching and its virtual monopoly of access to many of the most coveted state careers. Complaints against this monopoly began to be heard as early as 1796, but have availed little in the face of the unusual esprit de corps of the entrenched alumni. *Ecole Polytechnique* is not strictly a technical school, but it is doubtful if any other institution has had so wide an influence on higher technical education. Strict limitation of numbers, admission by *concours,* a closely prescribed curriculum with a strong mathematical bias, an arduous daily program and a strict regime of work, frequent individual interrogations, ranking by detailed records of daily work as well as examinations, the teaching of the sciences by eminent savants and of technical applications by active practitioners, mark all the French schools of engineering to this day. Many of these features were brought over by Thayer to West Point and by Greene to Rensselaer, whence their influence has spread throughout the United States. French example in creating higher scientific and technical schools entirely distinct from the universities has been followed by other continental countries with few exceptions. The plan of a distinct preparatory stage of scientific studies, followed by a specialized stage of technical application has strongly influenced all the technical schools of middle Europe.

The Conservatoire des Arts et Metiers.—The latter part of the 18th century was remarkable for the number and variety of prototypes of scientific education produced by France. The *Conservatoire* has the unique distinction of combining four of these in a single institution: (1) a museum of applied science, such as we are only now beginning to create in America; (2) a public scientific and technical library; (3) a group of professorial chairs for gratuitous instruction in applied science; and (4) a group of public laboratories for tests and research. The original conception is ascribed to the philosopher Descartes, but the *Conservatoire* itself grew out of a collection gathered by Vaucanson which he kept open to the public during his lifetime and bequeathed to the nation at his death in 1782. The Convention appointed a commission in 1794

> "to inventory and collect in suitable depots the books, instruments and other objects appropriate to public instruction"

and instituted under the present name

> "a public school of applied mechanics, supplied with a rich collection of machines related to all sorts of arts and trades, to serve on one hand for public demonstration and at the same time to give life to the teaching of the professors."

The collection grew rapidly and was installed in 1798 where it is today, in the ancient buildings of the Abbey of St. Martin, which have been repeatedly enlarged and transformed for this purpose. The public engineering lectures were instituted in 1819. The roster of the professors has always included names of the highest eminence. One of the widest known, General Morin, installed here before 1850 what seems certainly to have been the first teaching laboratory of engineering.

The Ecoles d'Arts et Metiers.—France must also be credited with the original type of engineering school of the mechanic arts. The primary conception was due to the Duc de Rochefoucauld who founded an industrial school on his domain at Liancourt in 1788 for the sons of the non-commissioned officers of his regiment of cavalry. The school was nationalized and transferred to Compiegne in 1799. Napoleon visited the school in 1803 and asked some of the older boys what career they planned to follow. The answer of "soldier" displeased the future emperor, in a mood at the moment for peaceful reforms, whereupon he addressed the school thus:

> "The State goes to much expense to train these young men and when their studies are finished, with the exception of the military training, they are of little use to the State. Nearly all become a charge on their families when they ought to be helping them. It will be so no longer. I have just come from a visit to the great factories of the northern provinces and Paris. Everywhere I have found foremen distinguished in their art, with great skill in execution, but almost none who was able to make a drawing, the simplest calculation of a machine, or express his ideas in a sketch or in writing. There is a defect in our industry—I intend to fill it here."

A few days later the official gazette announced:

> "The instruction at Compiegne will have as its purpose to train skilled artisans and heads of shops"

and bestowed the name *Ecole Nationale d'Arts et Metiers*. The school was moved a second time to more commodious quarters at Chalons in 1806 and continued on the level of a trade school until 1832, when the age limits of entrance were fixed between 15 and 17 and a *concours* of admission established. The levels of entrance and instruction have been further raised at intervals with the advance of preliminary education, but the early character of a school of mechanic arts for the production side of industry has been consistently maintained. A second school of identical type was established at Angers in 1815, a third at Aix in 1843. Certain politicians sought to suppress the three schools in the budgetary crisis of 1850, but the industrialists came to their defense with such vigor that their existence has never since been threatened. At that time they were the only technical schools in France outside of Paris. Additional schools of *Arts et Metiers* were created at Cluny in 1891, Lille in 1901 and Paris in 1912 and there is a strong demand for still further additions from certain provincial centers. Their present character as schools of industrial production resembles the Worcester Polytechnic Institute in its early years, but practical shop training is even more strongly stressed. In no other country is this type of training so definitely provided for.

Ecole Centrale des Arts et Manufactures.—Napoleon fostered great public enterprises in France and raised the engineering profession to a commanding prestige by his patronage, but it consisted almost wholly of public functionaries. When the Napoleonic era came to an end in 1815 the industrial supremacy of England, gained through private initiative, stood out impressively. France turned to the promotion of private industry, but there was no great center for the training of civilian engineers. The granting of a royal charter to the Institution of Civil Engineers in London in 1828 emphasized the contrast between the strong position of civilian engineers in Great Britain and their weak position in France. These influences led a group of French scientists, Dumas, Ollivier and Peclet, and an engineer Benoit, to join with a public-spirited capitalist Lavallee in creating a private school at Paris in 1829 for the purpose of training civil and mechanical engineers, heads of manufacturing establishments and teachers for technical schools. The principal ideas of the *Ecole des Travaux Publics* and the *écoles centrales* were resurrected and embodied in a program somewhat less abstract than that of *Ecole Polytechnique* to which was added an encyclopædic treatment of industrial technology. The cardinal doctrine of this unspecialized program was stated thus by one of the founders:

> "The science of industry is one and indivisible; every manufacturer or leader of industry must know it in its entirety or remain unequal to its tasks."

Ecole Centrale achieved a brilliant prestige from the start and students were soon drawn to it from a large part of the world. Lavallee at first sustained the school from his private fortune. The fees, amounting to 800 francs per year, yielded a considerable profit. When Lavallee retired in 1857 he refused the offer of a private corporation of 1,000,000 francs for his interest and donated the school to the State, asking only pensions for himself and his colleagues and reserving to the school its financial and educational autonomy. When *Ecole Centrale* was installed in its present quarters in 1884 the accumulated reserves provided $350,000 out of the total outlay of $2,150,000. *Ecole Centrale* exercised a foremost influence in the striking industrial progress of France in the middle portion of the last century. The *Société des Ingénieurs Civils de France* was formed around a nucleus of its graduates in 1848 and has always maintained a filial relation to the school.

As the pioneer school of industrial technology *Ecole Centrale* exercised a formative influence on all engineering education. The Rensselaer curriculum of 1849 * which became an almost universal prototype in America was largely adapted from the course of study at *Centrale:*

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* See p. 813.

CURRICULUM OF ECOLE CENTRALE, PARIS, 1850

Year I	Year II	Year III
Descriptive Geometry	Descriptive Geometry	Hydrostatics
Mathematical Analysis and Mechanics	Mechanics	Construction of Machines
Kinematics	Materials of Construction	Steam Engines
Physics (General)	Industrial Physics	Chemical Preparations and Organic Analysis
Chemistry (General)	Analytical Chemistry	Industrial Organic Chemistry
Chemical Laboratory	Chemistry of Industrial Minerals	Mining
Hygiene and Natural History Applied to the Arts	Geology	Architecture
Drawing	Public Works	Furnaces and Foundries
	Manufacture of Iron and Steel	Technology (Mills, oil making, spinning, felting, potteries, etc.)
	Technology (Cordage, textile materials, cutting of wood and stone, etc.)	Railways

The well marked sequences of this program will be observed. Evidently the crowded engineering curriculum is not altogether new. Prof. Greene of Rensselaer is said to have been much impressed in 1849 by the close application of the students with daily attendance from 8:30 to 5 and three or four hours of additional work outside. Under the private regime of the earlier years students were admitted by fairly simple examinations but when the State took over the school in 1857 it instituted a rigorous *concours* of admission similar to that of *Ecole Polytechnique.* Before that time about one-third of the students had been non-French, but the *concours* discouraged the attendance of foreigners which largely shifted for the time to the newly established Federal Polytechnic School at Zurich. This period may be taken to mark the end of the first great creative chapter in the history of higher technical education.

New Sources of Initiative.—The period from 1860 to 1890 was one of arrested development in French technical education, in striking contrast to the vigor of new growth in Germany and America. The State had made technical education its monopoly, but had subordinated it to its bureaucratic system. The higher schools were appendages of various bureaus and ministries, with no source of unified responsibility and initiative. The bureaus looked after their own needs with little concern for those of the country as a whole.

The *grandes écoles* at Paris concerned themselves only with preparing a limited *corps d'élite* of bureau chiefs and directors of industry, while the training of the numerous subalterns was largely neglected. Nothing had been done for the provinces in many decades, other than the creating of a small mining school at St. Etienne in 1816 and the development of the three early *Ecoles d'Arts et Metiers.* By the time local sources of initiative could be created to assume the burden the State had neglected, France had largely lost her early place of international leadership. The first efforts toward decentralization were made by civic bodies; then by the provincial universities in cooperation with regional groups of industries; and, more recently, by various professional and private agencies.

Action by Civic Bodies.—The initiative in creating schools of engineering to aid provincial industries came from civic bodies in the chief industrial centers. The *Ecole Centrale* of Lyons, established in 1857 under the patronage of the Chamber of Commerce, the *Institut Industriel du Nord,* founded in 1872 by the province of Nord and the city of Lille, and the *Ecole d'Ingénieurs* established in 1891 with the cooperation of the city of Marseilles, did much to lessen the gap. These institutions have maintained an intermediate position between the strongly industrial *Ecoles d'Arts et Metiers* and the highly professional *grandes écoles* of Paris.

The University Institutes.—The chief reason, perhaps, for the tardy development of engineering education in the provinces may be found in the state of impotence to which the universities of France were reduced by Napoleon in 1802. For nearly a century they remained mere aggregations of teaching faculties without administrative unity and initiative. The reform of 1896 constituted them as true educational organisms, capable of adapting themselves to a changing rather than a static social order. One of the immediate results was the establishment of a group of *instituts techniques.* The faculties of sciences at Nancy and Grenoble took the leadership in the new movement. With the aid of regional groups of industries they have built up in the last thirty years a flourishing group of technical schools. Their example has been followed at Lyons, Toulouse, Marseille, Lille, Caen and other provincial universities, with the result that the centralization of the earlier period of bureaucracy is rapidly being corrected.

Private Enterprises.—The failure of public initiative left a large area open to private enterprise, especially in Paris. The *grandes écoles* held to a restrictive policy which left many important interests unserved. For example, there was no provision in France before 1891 for the education of the subalterns in the State administration of public works. It occurred to M. Léon Eyrolles, an engineer of the *Corps des Ponts et Chaussées* who had interested himself in the training of his subordinates, that there was a need of a school for this purpose. He began modestly with four pupils and sent the lessons by mail to a few other at a distance from Paris. As the institution met a real need it developed rapidly, both as a resident school and a school of correspondence and gradually extended its field to industrial pursuits as well as State services. Lecture rooms were established in the heart of Paris, where university teachers and engineers in practice could serve as professors, and a school of practice was developed on an extensive tract in the suburb of Arcueil, thus solving the acute problems of space and accessibility. The *Ecole Spéciale des Travaux Publics, du Batiment, et de l'Industrie* has grown to be the largest and most diversified of the technical schools of France, and the one most resembling an American institution. Its work has gradually been raised to a level approximating that of the *grandes écoles* and it surpasses most of them in facilities for practical instruction.

A half dozen other schools, specialized on electrical and mechanical engineering, have grown up on private initiative in Paris in the last twenty years.

The Modern Schools of Specialization.—The latest chapter in the development of French technical education is especially worthy of consideration. It began with the founding of the *Ecole Supérieure d'Electricité* at Paris in 1894 by the *Société Francaise des Electriciens* as an adjunct to its central testing laboratory. The project owes much to the initiative of

Mascart and is probably the first and most important educational institution to be sustained by a professional society of engineers. With the aid of funds subscribed by the electrical industries, the school has recently completed a new and admirable plant. It provides an advanced and specialized program of a single year for men who have already completed a general technical education such as that of *Ecole Centrale.* This type of program, which is known in France as a *cours de perfectionment* or an *année complementaire* is now being adopted in other special schools, conspicuously in the *Ecole Supérieure d'Aeronautique et de Construction Mechanique* which is devoted to the aeronautic and automotive industries and is attended principally by graduates of *Centrale* and *Arts et Metiers.* This school, founded in 1909 on the personal initiative of General Roche, has since been recognized by the State as a school of application for graduates of *Ecole Polytechnique* destined to the State services and has been placed on a semi-public basis. The most recent addition to the graduate schools of specialization is one devoted to foundry practice, in connection with the Paris *Ecole d'Arts et Metiers.*

Retrospect.—It may help us to estimate the profound influence of France in the formative period of engineering education to choose the years 1750, 1800 and 1850 for a series of retrospective views. At the first of these dates France alone had a recognized profession of engineers and a school for their recruitment and training, created within the hands of the profession itself. In 1800 the engineering profession was first emerging in England and could scarcely be said to exist in the United States. There was then no school of applied science in the English-speaking world. Germany was a scattered group of agricultural states, possessing two small mining academies and a feeble school for surveyors and builders. At this period France had two flourishing schools of application for civilian engineers and two others for military functions; she had created the most notable scientific school of the period to assure the recruitment and intellectual culture of a *corps d'élite* of engineers and had engaged her most illustrious scientists in their training; she had created the first great museum of science and engineering; and she had formed in embryo the original group of schools of mechanic arts.

In 1850 Paris was still the world's leading center of engineering education. Great Britain could boast but three struggling centers of engineering instruction, each with a single professorial chair. The United States had but one established school of civil engineering, recently reorganized under French example, and three other schools of applied science in rudimentary stages of development. Germany was in the early stages of her great industrial advance with eight rapidly developing polytechnic schools, three mining academies, and numerous technical schools of lower rank. Switzerland had not yet established her Federal Polytechnic School, but had excellent cantonal schools of middle rank. France had strengthened her position in the half century by creating a renowned school of manufactures, by establishing a group of professorships, notable evening courses and a laboratory of engineering at the Paris museum, and had raised her three schools of mechanic arts to an advanced level.

In 1850 the period of French ascendancy was drawing to its close. The brilliant originality of the revolutionary period had burned itself out. France was entering upon a phase of stable population and internally balanced economic life. There was little population pressure to urge her people toward industrial penetration in outside markets. There was a period of instability in government which checked public initiative and discouraged private enterprise. The disaster of 1871 stripped France of some of her most important mineral and industrial resources and seriously impaired the national optimism. While the French engineering schools maintained unimpaired their high intellectual traditions, they fell behind first the Swiss Polytechnic School and later the rapidly advancing schools of Germany and America in enrollment, material equipment and financial resources. The competitive scheme of admission diverted the rising stream of foreign students first to Switzerland and later to Germany. Being wholly dissociated from the universities and dominated by bureau chiefs and practitioners, the dominant French schools failed in large measure to develop as primary centers of creative effort. Meanwhile the immense growth of research in the hands of professional teachers and investigators in the German *hochschulen* steadily overshadowed the more brilliant but less creative teaching of France. Public initiative under bureaucratic influence failed to foresee and to provide for the developing needs of the country. Local and private initiative finally undertook to close the gaps. In the meantime French technical education passed from its early phase of universal influence into a self-contained phase, effective for France, but of secondary significance beyond her borders.

B. Great Britain

Two Paths of Development.—British technical education has evolved along two divergent paths, quite unlike in their origins and their guiding philosophies. One had its beginnings in a welfare movement for workingmen and the neglected youth of the cities; it aimed to create, in Huxley's phrase, "an educational ladder reaching from the gutter to the university" through part-time and evening instruction for industrial workers. The second path grew out of the pursuit of science in the more progressive institutions of higher learning; its ideals have been those of research rather than immediate welfare, and its goal the creating of a direct link between creative science and practical industry. Both paths have ramified and interconnections have been created in recent years, and there is gradually evolving a fairly balanced and integrated national system.

Traditions Growing out of the Industrial Revolution.—Industry, higher learning, scientific inquiry and training for the professions grew up apart in England and the traditional barriers are not yet wholly obliterated. British industry was the outgrowth of invention and individual enterprise. In its origins it owed little to formal scientific inquiry. Its pioneers were workingmen, trained by apprenticeship and self-taught in rudimentary science. Newcomen was an iron monger, Brindley a mill-wright, Arkwright a barber; Crompton and Hargreaves were weavers, Smeaton and Watt instrument-makers. Telford, a dominating figure in the early years of civil engineering, began work as a son, the father of the locomotive, was an illiterate learned to read in an evening school in order to gratify scientific and mechanical curiosity. A deep-rooted tradition grew up around these names. One reads, for example, of "the school of Stephenson." It was assumed that a succession would rise from the ranks of artisans through sheer native ability, helped on by such science as an evening school could teach. The earliest efforts in technical education were prompted by welfare motives. The idea of creating a distinct professional group to specialize on the application of science to industry remained largely alien to much of British thought until the closing decades of the last century, when it was impossible longer to ignore the result of the professionalizing of scientific research and application in Germany and other rival countries.

stone mason.
stephen-
an illiterate fireman who —
gratify his —

English science down to 1850 was not only cut off from direct contact with industry, but was equally cut off from the chief centers of learning. The brilliant work of Rayleigh, Davy and Faraday at the Royal Institution casts a deep shadow over the older English universities of the same period. Higher learning was largely in clerical hands and a monopoly of the leisured classes, with little direct connection with the more active professions. Between university and industry there was an open gulf. Oxford and Cambridge preserved the mediæval plan of a congeries of residential colleges, admirably suited to literary culture but ill adapted without a strong central body to scientific inquiry and professional disciplines. The Scottish universities, like those of continental Europe, were organized by faculties rather than colleges and were far in advance of the English universities in scientific effort and professional teaching. The modern universities of England which have shown marked hospitality to pure and applied science and to other professional disciplines in the past half century owe much to Scottish inspiration and example.

Before the advent of the modern professional school the traditional form of training for a profession in England was that of individual pupilage. A group of old laws from the times scribed an apprenticeship of seven the sole mode of entrance to trades and professions was repealed in 1814. This act threw open all but a few callings at the very time when engineering was emerging from the hand-craft stage. The new profession was born under the individualistic star of the industrial revolution. The rise of the industrial system had opened up vast areas of enterprise to middle and lower class groups long excluded from the traditional privileges of rank and title. These newly found opportunities to rise were jealously guarded. Industry was conceived as a private calling and engineering an open profession to be kept as free as possible from state regulation and the old system of social caste.

Pupilage.—The newly formed profession of civil (i.e. civilian) engineers became a self-regulating body rather than one restricted by law. The leading engineers of this early period were themselves products of the old system of indenture and accepted pupilage as the recognized form of professional training. It would not have occurred to them to set up a school for engineers. The Institution of Civil Engineers, founded in 1818 and chartered in 1828, was conceived by its founders to be an agency of mutual education to supplement the limitations of the scheme of pupilage. Only three of its first ten presidents had the advantage of university training and they were of Scottish birth and traditions. An official account of the founding of the Institution states *

> "It was toward the end of the year 1817 that a few gentlemen, then beginning life, impressed by what they themselves felt were the difficulties young men had to contend with in gaining the knowledge requisite for the diversified practice of engineering, resolved to form themselves into a society."

The original by-laws of the Institution explicitly accepted the system of training by pupilage by prescribing that a Member

> "shall have been regularly educated as a Civil Engineer, according to the usual routine of pupilage"

and by enrolling as Graduates those

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* *Trans. Inst. C. E.*, Vol. 1 (1836), Introduction.

> "who shall not have been less than two years in the office or works of an engineer."

Apprenticeship to a trade commonly began at the age of 14 and continued to the majority. Pupilage was a more individual relationship which began at about 17 after a fair general education of the grammar school type. The principal received a premium of from £100 to £500, according to his reputation and influence, and paid no compensation for any service rendered by the pupil. In return he agreed to instruct the pupil in the arts of design and construction, to provide opportunities for observation and experience and to use his professional influence to give the pupil a favorable start at the end of his period of indenture. Pupilage at its best was a fairly effective initiation to the art, but it had characteristic hazards from which abuses not infrequently arose. The principal was often preoccupied and turned his pupils over to a subordinate, whose teaching was likely to be routine and imitative; there was a temptation to take more pupils than could be given active employment for the sake of profit; the pupil ran the chance of idleness in periods of slack work; and he was tempted to adopt the view that exact science had only an incidental relation to engineering. In many cases the result was little more than an acquired store of empirical standards, formulæ and dimensions. In time the Institution of Civil Engineers recognized the need of some guarantee of adequate scientific attainments and introduced its system of entrance examinations in 1897.

With the growth of large scale industry and its attendant specialization pupilage gradually declined. Vestiges of the premium system remain to the present day. Powerful hands have sought from time to time to give the system a death blow. Prof. Sylvanus Thomson characterized the premium-pupil system as "the worst enemy of technical education" and "the curse of British engineering." In a vigorous editorial in *Engineering* H. W. Maw scored the system as "a plan drawn up with the object of keeping out men who have brains but not money." While pupilage has almost wholly disappeared as a primary form of training, apprenticeship as coordinate with systematic schooling bids fair to remain a permanent institution. The early schools of engineering made no pretense of displacing pupilage—their training was avowedly auxiliary. The obstacle against which they had to contend was not so much the pupilage system as an attitude of distrust toward scientific methods. The pioneer professors, even men of the caliber of Rankine and Fleeming Jenkyn, were sometimes referred to in mild contempt as "hypothetical engineers."

The Voice of the Profession.—From its foundation in 1818 the Institution of Civil Engineers has exercised a dominant influence on the professional training of engineers. British policy is to leave such matters to the organized profession rather than the law and the professional institution, by virtue of its charter, acts as a quasi-legal body. The first notable British utterance on the education of engineers was the presidential address of Sir John Fowler in 1866, which took fairly advanced ground for the times:

> "Taking a boy of fourteen who possesses the requisite qualifications and with a determination on his own and his parents' part that he shall be made an engineer, the period from fourteen to eighteen should be devoted to the special education required by an engineer, during which mathematics, natural philosophy, land surveying and levelling, drawing, chemistry, mineralogy, geology, strength of materials, mechanical motions and the principles of hydraulics should be thoroughly mastered."
>
> "To accomplish these studies and make, in addition, considerable progress in living languages—German and French especially—it will be necessary to sacrifice to some small extent his classical studies and pure mathematics. At eighteen the boy, if duly prepared, may either be placed at once in the office of a Civil Engineer for a period of four or five years' pupilage, or he may be placed in a mechanical workshop, or he may be sent to one of our great universities. . . . If the boy is to go to the university, it is indispensable that all preliminary professional work, such as practical knowledge of mechanics, mechanical drawing, surveying and levelling, should be mastered in advance, because it can scarcely be expected that he will submit to the drudgery of learning them after his return from a three-year university course, then at the age of say twenty-three."
>
> ". . . With respect to the special preparation of young men between the ages of fourteen and eighteen several of the largest and best proprietary schools and colleges have special classes and departments for the study of applied sciences, and thence well-prepared pupils are sent out annually to commence their careers with engineers, architects and surveyors, but still the

> character of this special preparation in theoretical branches is not considered to be quite equal to that of France or Germany. . . . In practical branches we are admittedly superior. Let me be guarded against the possibility of being understood to suggest that this theoretical equality ought to be obtained by any sacrifice whatever of our undoubtedly great practical knowledge; indeed, on the contrary, I think that the attention to the greater opportunities which young engineers in this country enjoy by reason of the number and character of our own public works, than is obtainable in other countries, should be constantly encouraged to the utmost possible extent, and that our superiority as practical engineers should ever be maintained.''

Sir John Fowler's address led the Institution to make an extended inquiry and report on *The Education and Status of Civil Engineers in the United Kingdom and in Foreign Countries,* to which further reference is made on page 35. In 1895 Sir Benjamin Baker recalled the above passages in his own presidential address and added:

> ''Since that time so much has been done that, with the aid of public institutions, training of the kind indicated by Sir John Fowler has been brought within reach of every working man's son. If anything more remains to be said on the subject, it must therefore be of the nature of a warning, that technical education is of little value unless accompanied by the practical experience, sound judgment and bold initiative, which, rather than book knowledge, characterized the famous members of this Institution in the past.''

In 1903 the Institution in coöperation with eight other technical and professional societies appointed a consultative committee to consider and report on the whole subject of engineering education under the chairmanship of Sir William White. This committee dealt with the problem in its broadest dimensions, including the coördination of preparatory education, training in offices, workshops and factories, universities and other higher technical institutions. The report was a milestone, in that it placed the sanction of the profession clearly behind the system of higher education in engineering including post-graduate study and research. It was largely influential in fixing the norm of present-day engineering education in Great Britain, especially in universities, and is more fully dealt with in a later section of this study.

The Beginning of Popular Technical Education.—No other country rivals Great Britain in public facilities for the technical education of industrial workers. The origins of the movement supply the key to its ideals and spirit. The oldest school of applied science in the English-speaking world is the present Royal Technical College of Glasgow, which traces its origin to a bequest made in 1796 by John Anderson, leaving all his means

> ''to the public, for the good of mankind and the improvement of science, in an institution to be denominated Anderson's University''

which was to be open to all classes and to both sexes. Anderson, as Professor of Natural Philosophy in the University of Glasgow, had organized classes in industrial science designed to attract employers and workmen as well as students. James Watt was his instrument maker and it was he who placed a model of Newcomen's engine in Watt's hands for repair, with results which all the world knows. Watt gained the better part of his education through his intimate association with Anderson and the latter was probably influenced by the later achievements of his protege in his plan to create a center for popular scientific education.

An early professor in Anderson's College, Dr. George Birkbeck, organized a special class for *the gratuitous instruction of the operatives of Glasgow in mechanical and chemical philosophy* in the belief that *men should be taught the principles of the arts they practice.* The italicized expressions accurately epitomize the dominant aims and ideals in British technical education for nearly a century. Birkbeck later settled in London and interested himself in a society of workingmen for mutual improvement which became the model for Mechanics Institutes throughout the United Kingdom. The movement flourished with vigor for a time, but had passed into a decline by 1850. The aims in view were sound, but the difficulties were little understood. The general state of elementary education was deplorably low. Secondary education was in private hands and largely limited to the leisured classes. Workmen were unprepared for scientific studies and the methods of imparting education for definite trades were still unknown. The movement was not without permanent fruit, however, for it laid the foundations of a number of important technical colleges, notably at Glasgow, Manchester, Halifax, Huddersfield, Liverpool and Keighley.

The Science and Art Movement.—A fortunate combination of inventive genius, business enterprise, natural resources and isolation from continental wars had given Britain a flying start of half a century in the race for the economic supremacy of Europe. This early success had bred a high sense of industrial superiority and a strong confidence in the sufficiency of practical, trial-and-error methods. The International Exhibition of 1851 at London revealed the fairly startling degree of progress being made by continental rivals, which was at once attributed to their more effective organization of scientific research and education. A cry of alarm arose. It was asserted that Britain ''would lose her strength and pride'' unless prompt measures were taken to meet the crisis. The Prince Consort, German by birth and training, proposed that the profits of the Exhibition, amounting to £186,000, be increased by a parliamentary grant of £150,000 and used to create agencies ''for the instruction of those engaged in the prosecution of arts and manufactures,'' including a great center of education in applied science at South Kensington.

Hitherto education in all its branches had been regarded in England as a field for private, denominational and local initiative. There was no national system of elementary and secondary schools and the universities were self-governing groups of colleges on independent foundations. Public aid to education took the form of grants in aid of private or local institutions. As there was no national educational authority a Science and Art Department was created under the Board of Trade in 1853 to direct the new effort. However, the force of tradition still prevailed. The plan for a great central institution was set aside and a scheme of money grants was instituted to encourage teachers and schools everywhere in the holding of classes in elementary science and applied art.

The ''capitation grants'' were based on the number of passes in a group of ''science and art examinations.'' While the result was not wholly good, due to the cramming process which the scheme encouraged, the plan was opportune and served to reanimate the evening classes for workingmen at a time when voluntary effort in the Mechanics Institutes was on the wane. The number of schools receiving grants rose steadily from 9 in 1860 to 2672 in 1895. In the latter year 190,000 students were examined and the grants amounted to £160,000. The Science and Art Department was merged in the newly established Education Department in 1857, but continued to exercise its original function until 1900, when it was replaced by the present Board of Education. At that time the entire scheme of public education, elementary, secondary and technical, was handed over to local education authorities under national inspection and with divided national and local support.

Origin of the London Polytechnics.—An important group of technical schools in London, known as Polytechnics, are the fruit of a welfare movement of interesting origins. In 1865 Mr. Quintin Hogg, quite single-handed, began a work for the religious and social welfare of neglected street boys in London. The growth of this work led him to acquire larger quarters which had formerly been used as a museum and a center for popular lectures on applied science. Hogg retained the original name of the premises, The Polytechnic Institution, and borrowed some of its associations, building up an educational and welfare institution of extraordinary effectiveness on which from first to last he spent over £100,000. A problem arose in the 70's concerning the disposition of the unexpended charitable funds which had accumulated from the endowments of certain parishes in the old City, depopulated through the encroachments of business. The Royal Commission appointed to deal with the problem, headed by Mr. (later Sir) James Bryce, visited Mr. Hogg's Polytechnic and was greatly impressed by its activities. They recommended that the surplus charity funds be used to enlarge the Polytechnic and to build seven others on a similar plan for the education and welfare of the poorer inhabitants of the entire metropolitan area. These institutions have since passed under the direction of the London County Council.

The City and Guilds of London Institute.—The mediæval guilds, organized for the self-government of industry and trade, regulated the training of apprentices until the advent of the factory system broke down the more personal relations of the ancient regime. The guilds or livery companies of London had built up great endowments, principally for educational purposes and have continued to exist as semi-public trusts after their original functions had entirely disappeared. There are still seventy-six of these companies and seven are especially powerful organizations. The Science and Art grants did not include the teaching of technological branches. The Society of Arts instituted a scheme of examinations in technology, as a supplement to the Science and Art examinations, but made no grants in aid. By 1875 the severe limitations of these examinations and grants as a supplement to the remaining vestiges of the apprenticeship system had become a source of serious concern. A tide of agitation arose for a more effective scheme of technical education. Huxley and Sylvanus Thomson took up the issue, protesting against taxing the rate-payers as long as the livery companies held vast educational endowments. The movement led to the organization of The City and Guilds of London Institute which began work in 1879 under a four-fold scheme of activity:

1. A system of technological examinations and grants-in-aid to supplement the work of the Science and Art Department. (Examinations and certificates are still maintained on a wide scale, but grants were discontinued in 1891.)
2. The establishment and maintenance of a technical school at Finsbury and a school of applied art at South Kensington.
3. Grants in aid of engineering education at University College and King's College, London.
4. The establishment at South Kensington of a central institution to give technical education of the most advanced character, for the training of engineers, industrial managers and teachers. (The City and Guilds Engineering College. now a constituent part of the Imperial College of Science and Technology.)

This act has been acclaimed as the most forward-looking of any in the entire history of British technical education. It broke down the old theory of private responsibility and placed it on a quasi-public body. It extended recognition and financial aid to the teaching of technology as well as science. It prepared the way for the creation of the great central scientific and technical institution foreseen thirty years before by the Prince Consort. The total of the donations and expenditures of the Institute up to the end of 1924 exceeded the sum of £1,200,000.

The school at Finsbury began its work in 1879. It was directed by able men, Sir Philip Magnus and Prof. Sylvanus Thomson among them, and exercised a formative influence on local technical institutions throughout Great Britain. Day classes were provided for persons of both sexes who wished to prepare for intermediate posts in industry or for entrance to the central school at South Kensington. Evening classes were organized for apprentices, artisans and foremen in five divisions: mechanical engineering, electrical engineering, technical chemistry, applied art and trade subjects. At the outbreak of the recent war financial limitations led the City and Guilds Institute to transfer the institution to the London County Council which maintained it until 1926 when it was closed on the plea of post-war economy.

Origins of the Local Technical Institutions.—A serious trade depression extending from 1884 to 1886 rekindled the fear of foreign competition. Again there was a widespread alarm over the inadequacy of British technical education. A Royal Commission of Inquiry prepared the way for a series of parliamentary acts which empowered the County Councils to create and maintain local technical schools and to appoint boards of "local educational authorities" to direct them. The Act of 1889 gave the term *technical education* a legal interpretation:

> "The expression *technical education* shall mean instruction in the principles of science and art applicable to industries and in the application of special branches of science and art to specific industries or employments. It shall not include teaching the practice of any trade or industry or employment."

The Act of 1890 handed over to the local authorities large sums from the customs and excise duties, known as "whisky money" to aid in the founding and maintenance of technical schools. Many old institutions, the outgrowth of mechanics institutes, science and art classes and aided classes in technology, were thereupon taken over by the local authorities. New institutions sprang up rapidly.

While ample funds were now available, there were still lions in the way. Elementary education had been made compulsory, under public regulation, as late as 1876; the school leaving age for the great majority was about 12 or 13; there was no national system of secondary education and a wide gap existed between popular and higher education; and the funds provided by the technical education acts could not be used to round out deficiencies on the literary side of education. The inevitable result was that most of the activity resulting from the acts gravitated to the level of junior or post-primary technical day schools and evening technical classes of junior or secondary grade. A few of the cities, notably Glasgow and Manchester, built up technical colleges which offered day instruction of the university standard as well as work of a more popular grade and which later became affiliated with neighboring universities as faculties of technology.

The Education Act of 1900 established a national Board of Education and handed over to the local authorities the operation of the entire scheme of public education. Since that time secondary education of an academic type has been greatly extended, leaving to the local technical schools the field of post-primary day education along industrial lines and the field of part-time and evening instruction in applied science, art and technology. Through the Act of 1900 fifty years of effort to create a system of popular technical education came to larger fruition in a comprehensive system of national education. The local technical institutions, now numbering more than two hundred in England and Wales, as well as twenty-one in Scotland, constitute the apex of the local scheme of education. They are certainly the most distinctive British contribution to education in applied science. The historical genius of these schools must be sought in a welfare motive. Huxley once described the British ideal of technical education in the apt phrase ''capacity-catching machinery.'' On another occasion he spoke of the task of ''building an educational ladder reaching from the gutter to the university, up which any child in the three kingdoms may climb as far as his capacity will take him.'' In no other group of institutions in this ideal more closely realized.

The Growth of University Engineering Schools.—The preceding sections are barely able to suggest how long and persistently Great Britain pursued the ideal of individual welfare in technical education and sought to bring to industry the fertilizing power of science through the ''education of hands rather than heads.'' It also suggests the traditional distinction between ''technical'' and ''university'' education—the one local and intimately associated with regional industries and the other non-local and closely related to scientific research. Between the two there is also the gap of matriculation and the degree but this has been appreciably lessened by the creation of a system of ''national certificates'' and ''national diplomas'' for non-degree courses.

The effort to create a system of higher engineering education in university colleges faced adverse odds from the beginnings in 1840 down to the close of the last century. The professional body jealously guarded the old traditions of practical training. Many of its leaders distrusted a less heroic discipline than that of ''work all day, study all night'' on which they themselves had been raised. Industrialists not infrequently viewed science with mild contempt as something remote and abstract. The premise that leaders are born and not made led to the inference that they would fight their way to the top with little aid and encouragement. The underpinning essential to professional schools of engineering was largely lacking. Nearly fifty years were lost through delay in creating a national system of secondary education with an efficient modern side. Oxford and Cambridge followed rather than led; physical science had scarcely a foothold in their precincts before 1850 and there was no provision for experimental study and research before 1870. The Scottish universities were of great service to applied science, as the names of Rankine, Jenkyn and Kelvin will suggest. The modern universities of England, which grew out of an older group of university colleges and have probably done more than any other agency to destroy the monopoly of classical learning in English education, date their history from 1880 and their rapid development from 1900. At the latter date there were only 345 third year and 52 fourth year students of engineering in the whole of Great Britain and many of them had entered at the age of 15. Since 1900 the gap which long separated England from her neighbors, in matters of higher education, has been nearly if not wholly closed.

The first of the university colleges was established under the name of the "University of London" in 1827. It was a proprietary institution without a charter. Its fees were low and no religious restrictions were imposed, the aim being to make a high standard of education available to students cut off from the older universities. There was a storm of criticism against this "godless institution" and a rival known as King's College was soon erected under Church auspices. These two colleges early became centers of active scientific inquiry. and were the first to introduce the teaching of engineering. Both established chairs of civil engineering in or about 1840 and there are evidences of still earlier teaching under other names. The chair of civil engineering at the University of Glasgow also dates from 1840. A Royal College of Chemistry was created in London on a private foundation in 1845. In response to numerous memorials from the mining industry a Government School of Mines was established in London under the Board of Trade in 1851 and was installed in the Jermyn Street Museum. Two years later the School of Mines and the College of Chemistry were merged under the direction of the newly created Science and Art Department. The University of Edinburgh established its chair of civil engineering in 1865.

Mention has been made on page 777 of the inquiry into the education and status of civil engineers in 1868 and 1869. This survey revealed how far continental Europe and the United States had outstripped Great Britain in the development of professional schools. Britain could show in all but seven centers of engineering instruction, all small and struggling, five having but a single teacher for all the engineering branches. There were meagre laboratories for the physical sciences and no engineering laboratories of any sort. University College, London, probably the first institution to introduce a complete engineering course and a recognized leader in 1870, may be taken as an example of the period. There was a single professor of engineering, entrance was permitted at the age of 15, there was no entrance examination and the enrollment numbered around fifty; the tuition fees for the three years' course amounted to more than £125; there was no engineering laboratory; and the curriculum of the period was as shown below;

UNIVERSITY COLLEGE CURRICULUM OF 1870

	Hours per Week		
	Year I	Year II	Year III
Arithmetic and pure mathematics	6	6	3
Applied mathematics	3		
Applied mechanics		3	3
Physics	3	3	
Physics laboratory			6
Chemistry	5		
Chemistry laboratory		4	
Civil engineering		3	
Mechanical engineering			3
Machine drawing and design	6	6	6 or 4
Surveying		1	
Geology	2		

These simple annals represent forty years of struggle against odds of indifference and neglect, yet the period was illumined by some notable personalities—Vignoles at University College, Wheatstone at King's, Huxley and Playfair at the School of Mines, Rankine at Glasgow and the many-sided Fleeming Jenkyn at Edinburgh.

The Turn of the Tide.—From 1880 on the fortunes of the university schools of engineering were in the ascendant. The City and Guilds of London Institute was the first public agency to take engineering education under its fostering care. It assisted University and King's colleges with money grants and established under its own auspices the City and Guilds Engineering College at South Kensington, adjoining the Royal School of Mines and the Royal College of Science. With the opening of City and Guilds College in 1884 England possessed for the first time an ensemble for teaching and research in technical science comparable to the many great schools of continental Europe and America. The Prince Consort's vision of 1851 did not reach its full consummation until 1907, when the three schools at South Kensington were federated into the Imperial College of Science and Technology, often referred to at that period as the British Charlottenburg. The tribute to the famous institution at Berlin is well deserved, for it is plain that the force which stirred England to action was German example and competition.

A second event of 1880 to mark the turn of the tide was the chartering of the first of the "modern" or "urban" English universities, Victoria at Manchester. This was an outgrowth of Owens College, established in 1851 to teach

> "such branches of learning and science as were then and might thereafter usually be taught in English universities."

Owens was a maker of precedents for the university colleges which arose in the chief provincial cities and later were erected into universities. These institutions owe more to the example of the Scottish universities than to Oxford and Cambridge. They were organized by faculties and departments rather than residential colleges and welcomed the physical and technical sciences from their earliest years. Their service to engineering education, in giving it the prestige of a place in the university system, can scarcely be overestimated.

The Period of Rapid Growth.—The example of Victoria ushered in a period of university expansion of almost unparalleled rapidity which swept engineering education forward with the tide. University College, Liverpool, was incorporated into Victoria University in 1884, followed three years later by Yorkshire College of Leeds. Mason College, Birmingham, founded in 1880, was chartered as the University of Birmingham in 1900 and came forward rapidly as one of the chief university centers of engineering activity. Victoria was separated into three distinct universities at Manchester, Liverpool and Leeds in 1903 and 1904. Firth College at Sheffield, founded in 1879, became a university college in 1897 and the chief nucleus of the University of Sheffield which was chartered in 1905. Sheffield has long been prominent as a center for the teaching of ferrous metallurgy. The University of London was created by federating University and King's colleges in 1836. In 1850 a new charter was given and candidates were admitted to degrees from affiliated colleges in various parts of the country. In 1900 it was reconstituted in its modern form as a federal group of teaching institutions with engineering departments at University College, King's College, East London College and the Imperial College of Science and Technology. The University of London continues to act as a central examining and degree-granting agency for a considerable group of other university colleges, polytechnics and local institutions. Bristol incorporated the Merchant Venturers' College (1885) as its faculty of engineering when it received a university charter in 1909. Reading became the latest accession to the university group in 1926. University colleges at Nottingham (1881), Southampton (1902), Exeter (1922) and of still more recent origin at Leicester and Hull, all pressing to the goal of university status, indicate the momentum of the present effort to make higher education in both its liberal and professional aspects as widely accessible in England as it has long been in Scotland, France, Germany and America. In the winning of this fight the early schools of engineering had no inconsiderable share.

The Older Universities.—The Scottish universities have traditionally preserved the union of liberal and professional education and were among the first to provide for the teaching of engineering. Durham instituted the teaching of civil and mining engineering in 1837, but the movement was short lived and it was not until 1871 that an enduring work was begun at Armstrong College at Newcastle, under the joint auspices of the University and the North of England Institute of Mining and Mechanical Engineers. Cambridge began to turn a friendly eye toward mechanical science soon after the physical sciences had been firmly established under Clerk Maxwell. Under the leadership of Prof. James Stuart workshops were installed and lectures on applied mechanics instituted in the 80's. Sir Alfred Ewing, Stuart's successor, was instrumental in placing engineering on a substantial foundation at Cambridge through the creation of an honours tripos in mechanical science in 1890 and the installation of an extensive laboratory. From that time on engineering gained rapidly at Cambridge; the enrollment had risen to 250 by 1913 and has since nearly doubled, making it the largest of the university schools of technical science. Oxford came into the field late and on a very modest scale. A chair of engineering science was established in 1909 and a laboratory erected in 1913, since which time Oxford has enrolled an average of about thirty students of engineering.

The Higher Technical Institutions.—The forces which were making for university expansion were at the same time transforming a group of local technical institutions into higher schools of engineering. The Glasgow and West of Scotland Technical College was created out of Anderson's College and two other institutions in 1886; nine years later it occupied a magnificent plant erected by popular subscription; in 1912 the King bestowed its present name, the Royal Technical

College; and a year later it became affiliated with the University of Glasgow as a faculty of technology. Heriot-Watt College worked out a similar relationship to the University of Edinburgh and Robert Gordon College to the University of Aberdeen. Under the technical education acts of the late 80's the city of Manchester developed an old school of secondary rank which traced its origin to the Mechanics Institution of 1824 into a great Municipal College of Technology. The city sent a mission of inquiry to the chief continental centers of technical education and in 1902 erected one of the most extensive educational plants in Great Britain. Three years later the College became affiliated with Victoria University as a faculty of technology, at the same time retaining its functions as a local technical institution. These instances were part of a widespread movement through which the educational ladder from the gutter to the university, of which Huxley spoke inspiredly in the 70's, has become at last a reality.

Dominant Influences in the Last Fifty Years.—In the brief scope of this study it is not possible to unravel fully the complex forces at work in the transition of the last fifty years. Only a few outstanding strands can be traced. The boldest of these was the persistent fear of industrial competition from abroad. From 1850 on every wave of popular concern over technical education can be identified with a trade depression or some disquieting challenge from French, German or American industry to Britain's traditional faith in her inventive genius, practical skill and business sagacity. This attitude was never more active than it is to-day. The war and the post-war depression have created a new attitude toward science. Stanley Baldwin has struck the keynote of the moment in his declaration "the future rests with the nation which is most successful in harnessing science to industry."

The story of British technical education is one of movements, usually groping their way by trial and error, rather than one of dominant leadership by men and institutions as in France and Germany. There is one individual, at least, whose leadership deserves a special tribute—Dr. H. W. Maw, senior editor of *Engineering* from 1870 to 1924, whose pen was seldom silent on the problems of engineering education. Beginning with the first issue that came from his desk Maw campaigned incessantly for a sound educational policy, analyzing the special problems of technical education at a time when these were little understood, urging the need of a sound underpinning of elementary and secondary education, pointing to the inadequacy of ''broadcasting elementary scientific information'' through the Science and Art classes, holding up as a challenge the best that was being done in other countries, and reiterating constantly the necessity for creating a few engineering schools of the highest scientific rank. Only one brief fragment can be given to illustrate the force of Maw's editorial style:

> ''We are spending more than a million a year out of the rates and taxes on technical training and very much of it is wasted. The teaching of young mechanics and others the elements of science and handcraft, though not without value, is of little advantage in meeting the competition of Germany and America. It is equivalent to teaching private soldiers the principles of strategy.''

Maw did his work through his leading editorials, of which he devoted an average of more than five a year for over fifteen year to educational subjects, the maximum rising to ten in 1897—a record unapproached in the history of engineering journalism.

Great influence was wielded by a series of educational missions abroad. Once awakened from her complacency, England sought to know and use the best that had been created in other lands. One of the most interesting of these missions was sent to America in 1902 at the personal expense of Mr. A. Mosely. The mission was prompted by Mr. Mosely's observation of the work of a group of American mining engineers in South Africa to whose technical skill, resourcefulness and business sagacity ''the primary success and subsequent prosperity of these mining centers was due.'' The mission was charged to consider:

The development of individuality in primary schools;
The social and intellectual effects of the wide distribution of secondary education; and
The effect of specific instruction given (*a*) in business methods and (*b*) in applied science.

The report of the mission emphasized particularly the greater practicality and accessibility of higher education in America.

The breaking of the monopoly of secondary and university education long held by the leisured classes was profoundly important to engineering education. The contrasting records of England and Germany reveal in a striking way the indispensable role of a system of secondary education which is accessible to all social classes and offers equal resources for scientific and literary culture in the upbuilding of higher engineering education. As long as such a system was lacking in England, the university schools of engineering struggled against hopeless odds; since its creation, their development has been notable, but the delay cost nearly fifty years.

A final lesson from the record of Britain stands out with special boldness—there is nothing more perilous to industry than the dissociation of technical education from high and disinterested scientific research, a defect long tolerated but now happily corrected. While the universities and local technical schools have not become wholly differentiated in function and probably should not be, in principle and increasingly in practice the former tend to unite technical education with fundamental research and the latter with the immediate needs of industry through the medium of part-time instruction. An effective balance between the two is still incompletely worked out, but the situation is rich in its possibilities.

C. The German States

Technical Education and Statecraft.—The resurgence of the German states after the defeat and dismemberment of the Napoleonic era was the historical miracle of the 19th century. Awakening fully for the first time since the middle ages, Germany threw off her mood of futile romanticism and turned toward the future with a resolute realism. This break with the past gave a great impetus to new forms of education and scientific endeavor. Far-seeing statesmen began deliberately to rebuild the old agricultural states into the modern industrial empire. There is probably no other region, great or small, in which technical education and research have had so large a share in shaping national destiny. Witness the testimony of the eminent French sociologist, Charles Gide:

> ''It is technical education, patiently pursued, conscientiously assimilated, which has been for Germany an arm more powerful than the spirit of enterprise of the English and the artistic feeling of the French. She owes to it her admirable commercial and industrial advance.''

The initial impetus came largely from state sources early in the last century. The states had important monopolies and industrial interests of their own—forests, mines, communications and manufactures of military material—and stood in need of trained technicians for their development and officers for their administration. The industrial supremacy of Great Britain was a source of bitterness. Manufactures which had been set up under the ''continental system'' of Napoleon were not standing up in competition with England and Belgium. Industry was everywhere in low esteem among the higher classes, state employment everywhere desired. The national heritage of natural resources was relatively meagre. Capital for the expansion of industry was scarce; as the states could not create it, they turned to the creation of skill and intelligence as the remedy for the economic ills of the moment and the guarantee of future security.

The Roots of Technical Education.—The transition from the traditional system of apprenticeship to modern forms of technical education began under difficulties in Germany, but was ultimately carried through with unexampled thoroughness. Late in the 18th century there were tentative efforts to give technical education a place in the universities, by introducing the teaching of chemical and mechanical technology dressed up in the Latin name ''cameralia.'' In 1773 Prof. Eberhard lectured on applied mathematics at Halle, but his efforts to secure a recognized place in the curriculum for this and kindred subjects met with refusal. Heidelberg and Göttingen also made tentative beginnings in technical branches of science at about the same period.

As soon as the issue was clearly defined, however, the ruling academic party refused to admit the technical sciences, regarding them as wholly alien to their cherished ideals and traditions of disinterested learning. The result was a sharp cleavage between academic and technical education. The gymnasium and the university stood together as a closed system and an entire group of new institutions had to be built up completely from the ground. The early technical schools had no choice but to superpose their programs on the *volkschulen* of the common people and were therefore scarcely more than trade schools. To create a group of technical schools equal in all respects to the universities was the work of a century and would have been impossible without the creation of a modern type of secondary school as a counterpart to the classical gymnasium. The rise of the *technische hochschulen* and the *oberrealschulen* was essentially a single movement. The two made common cause and achieved a common triumph. No historical situation shows more clearly the intimate dependence of higher technical education on a sound and sympathetic scheme of secondary education, unless it is the retardation of half a century which resulted in Great Britain from the lack of such an underpinning.

The First Technical Schools.—Having been cast out by the academic powers that were, technical education was nurtured in its infancy by officers of state. Prince Xaver of Saxony founded a royal *bergakademie* for the teaching of mining and metallurgy at Freiberg in 1765. Intended primarily for the training of state mining functionaries, the *bergakademie* remained a small and provincial institution for a long period. Its indirect influence was great. It deviated from the universities in combining theoretical teaching with practical work in laboratories, inspection of mine working, journeys of observation and actual work in technical callings, procedures later adopted and greatly developed in the *technische hochschulen.* The principle of *lehr- und lern-freiheit*—the freedom of the teacher to teach and that of the student to study what he chooses—which is so jealously guarded in all higher institutions in Germany was here observed from the beginning. It was introduced into the universities by von Humboldt, who became acquainted with it as a student at Freiberg. Toward the middle of the last century Freiberg gained an international renown and was largely attended by foreigners.

In 1799 Frederick William III of Prussia established a royal *bauakademie* at Berlin for

> "the theoretical and practical training of skillful land surveyors, civil and hydraulic engineers, especially for the royal states, to which training foreigners also are admitted, in so far as this can be done without prejudice to native pupils."

While the aims of the *bauakademie* were ambitious it was actually a school of elementary character. Students were permitted to enter at the age of 14 with only a common school education. There was a course of study for surveyors of three semesters and one for constructors of five. It is worthy of note that the traditional hospitality to foreign students which has contributed so much to the renown of the German engineering schools was foreshadowed in the original plan of the *bauakademie.*

The states of the old Austrian empire made beginnings in technical education at about the same period. In 1801 the state of Bohemia commissioned Count von Gerstner to draw up a plan for a polytechnic school in Prague, under the influence of French example. The school was opened in 1806; like the building school at Berlin it admitted students at the age of 14 with common arithmetical preparation. The Polytechnic Institute of Vienna, established in 1815, had a preparatory section or *realschule* of two years which could be entered at the age of 13 and a higher technical section with a three-year course. The later development of these schools has closely paralleled that of the schools in Germany proper.

The Rise of the Technical Universities.—The rise of a group of institutions from the level of trade schools on the borderline of elementary education to a powerful and homogeneous group of universities, together with the inseparable upbuilding of modern secondary schools, has been acclaimed as the greatest achievement in educational organization in the Germany of the 19th century. Three distinct periods may be discerned in this evolution; (1) a trade school period marked a diversity of origins and types and extending from 1799 to 1835; (2) a period of transition from trade schools of narrow purposes to polytechnics of wide scope and professional rank, extending to 1875; and (3) a period of development on a university plane extending to the present, but notably marked by the official bestowal of full university prerogatives in 1900. To trace the evolution of each of the present eleven technical universities would be beyond our present purposes. The story may be epitomized by outlining the growth of the two which probably had the largest influence in shaping the common norm of today. Karlsruhe had the greater renown and formative influence in the two earlier periods, but Charlottenburg came to have a commanding position in the later stage, after Berlin became the seat of imperial influence.

Karlsruhe.—Agitation in the state of Baden for the establishment of a polytechnic school began to gather force as early as 1808. The leader of the movement was Nebenius, liberal statesman and economist, who re-drafted the constitution of Baden, built its railways, revised its scheme of taxation, reorganized its education and was largely influential in creating the customs union. Nebenius was familiar with the great technical schools of Paris and sought to create in Baden a school of more general scope which would train leaders for industry as well as officials for the state services. The polytechnic school at Karlsruhe, the first of its kind in Germany, was created in 1825 by combining an older state school of civil construction with a private industrial school.

It was not clearly perceived at that time that schools of different types were needed for the training of artisans and directors. Instead the effort was made to make the same program meet both needs by merely varying the length of the course of studies. Nebenius soon grasped the need of a separation. He urged the creation of distinct schools, one aiming at much skill with a modicum of scientific knowledge (*fachschule*) and the other at a high scientific discipline with less dexterity (*hochschule*). In 1833 Nebenius reorganized Karlsruhe on the latter pattern, which he felt must precede the former in its development. This point marks the cleavage between the higher, middle and lower technical schools of Germany. From 1833 on Karlsruhe was essentially a professional school with an internal organization resembling the universities. The faculty was a self-governing body, choosing its own rector annually. The Prussian schools did not attain a like degree of autonomy until near the middle of the century.

The curriculum of Karlsruhe in 1833 was advanced for so early a period. There was a preparatory realschule of two years which could be entered at the age of 13; then followed a general scientific section of two years on the lines of the *Ecole Polytechnique* of Paris; and there was a final stage of application with separate sections for architects (6 semesters), for civil engineers (4 semesters) and foresters (4 semesters). A later reorganization in 1863 foreshadowed in some detail the present norm of a technical university. The *realschule* was dropped and admission was based on a *realschule* certificate, with a minimum age of 17; the general scientific section of two years was retained; and the professional sections were enlarged to include architecture, civil engineering, building construction, chemistry, mechanical engineering, forestry, commerce and postal services. The revised curricula began and ended on much the same levels as those of the better engineering schools in America at the present. The title of *hochschule*, which serves as an inclusive term for all institutions of university rank and character in Germany, was not adopted until 1885.

Charlottenburg.—The original nucleus of the present technical university at Charlottenburg was the *bauakademie* at Berlin, founded in 1799. The first definite movement in

Prussia to promote the growth of manufactures through technical education appears to have been made on the initiative of the eminent state councillor Beuth, who established in 1822 at Berlin a *technische schule* which soon developed into a complementary institution to the older *bauakademie.* It was at first a simple trade school which pupils might enter direct from the elementary school at the age of 14. The rise of its standards was reflected in successive changes of name to *gewerbe-institut* in 1827 and *gewerbe-akademie* in 1866. Beuth reorganized both the *bauakademie* and the *gewerbe-institut* in 1849, raising the minimum age of admission to 17 with the additional requirement of a *realschule* certificate. The courses of study were placed on a thorough and practical basis and given an engineering character. It was at this time that the principle of *lehr- und lern-freiheit* was first introduced into the polytechnic schools. The course of study at the *bauakademie* of 1850 consisted of three years in common for civil engineers and architects, followed by one year of specialization. The curriculum of the *gewerbe-institut* covered three years and there was an additional requirement of a year of industrial experience. The instruction in the first two years was devoted to higher mathematics, physics, chemistry, drawing, mechanics, mechanism, metallurgy and machine construction; while the final year was divided into separate sections for chemistry and mechanical engineering, in order to give the students a more detailed introduction to industrial applications.

The victory over France in 1871 with its attendant conquest of Alsace-Lorraine, the unification of the German Empire and the vigorous economic policies of Bismarck gave an immense impetus to the industrial expansion of Prussia which was quickly reflected in the growth of the technical schools. As the two schools in Berlin had begun to overlap appreciably, the State combined them into a polytechnic school in 1876 on the lines of Karlsruhe and the Swiss Polytechnic School at Zurich. Three years later the title and status of *hochschule* was bestowed, making the institution a university in all except name and the right to award degrees. Prussia now set itself to house the united institution, the largest of its type in Germany, on a scale of unexampled magnificence. A group of buildings was erected in the suburb of Charlottenburg at an outlay of $2,500,000 and was dedicated in 1884 by the Emperor William I in person, with the most impressive signs of imperial favor. This event reacted strongly on the prestige of technical education and placed Charlottenburg in a position of leadership. At the celebration of the centennial of the old *bauakademie* in 1899 an even more significant event occurred, the official recognition by the Emperor William II of the equality of modern and traditional forms of education and the bestowal upon the *hochschule* at Charlottenburg of the formal prerogatives of a university, including the right to award the degrees of *diplom-ingenieur, doktor-ingenieur* and *doktor honoris causa.* The King of Wurttemburg at Stuttgart quickly followed the imperial example and within a short period all the nine existing *technische hochschulen* were invested with similar rights.

The Rise of Other Hochschulen.—Under similar influences and in like stages to those which prevailed in Baden and Prussia, the other German states built up their technical universities from diverse origins into the highly homogeneous type of today. Hesse laid the foundations at Darmstadt in a *realschule* in 1822 and advanced its rank successively to a higher industrial school in 1836, a polytechnic school in 1864 and a hochschule in 1877. A *gewerbe-schule* on the lines of the *Ecole d'Arts et Metiers* at Chalons was established at Dresden in 1828 and was reorganized into a polytechnic in 1851. It was given the rank of *hochschule* in 1871 and the state of Saxony installed it in a costly plant in 1875, which marked the beginning of a period of competition between the German states in the material development of these schools. At Stuttgart an industrial school was created in 1832 out of a special class for draftsmen and artisans in a *realschule,* which became a polytechnic in 1840 and a *hochschule* in 1876. A higher industrial school established at Hannover in 1831 became a polytechnic in 1847 and a *hochschule* in 1880. The state of Bavaria founded a central polytechnic school in Munich in 1823, but the school was broken up in 1827 into three, one remaining at Munich, one being placed at Nuremberg, and the third at Augsburg. The Munich school continued as a school of architecture until 1868, when it was restored to the status of a polytechnic. It was recognized as a *hochschule* a few years later, while the schools at Nuremberg and Augsburg continued as technical middle schools of the higher class. The Collegium Carolinum at Brunswick, founded by the Abbot Jerusalem in 1745 and one of the first of the German secondary schools to have a technical division, was modernized into a polytechnic in 1835 and advanced to a *hochschule* in 1877. Aachen was created as a fully developed *hochschule* in 1870, after which there was a lapse until Prussia established new technical universities at Danzig in 1904 and at Breslau in 1910 to serve its eastern regions.

Dominant Influences.—The influence of French example is apparent in the earlier years of German technical education, but a distinct national type began to emerge in the polytechnic schools under the leadership of Karlsruhe in the middle period. The rising *realschulen* pushed up the standards of entrance, while the emergence of a distinct group of technical middle schools tended to emphasize the professional aims of the polytechnics.

The pioneer work of German chemists, although largely carried out in the universities, strongly influenced the destinies of the technical schools. The laboratory which Liebig created at Giessen in 1824 became a fountain head of teaching and research. Students were attracted from all parts of the western world and Liebig's influence on his American disciple Horsford furnished much of the inspiration for the creation of the Lawrence Scientific School at Harvard. Liebig and his followers awakened Germany to the future possibilities of chemical industry, with the result that great laboratories were created in many of the university centers. The progress of the chemical industries as slow during the first half of the century and only moderate in the third quarter, but during the last quarter it became fairly irresistable. Success in appropriating chemical manufactures revealed the economic possibilities for industry in the researches of experts and Germany was quick to extend the same procedure into other realms of industrial technology. Probably the greatest contribution to industrial progress which has come out of Germany was this demonstration of the potency of *the professional organization of scientific research and of technical application.* The prompt seizure of this idea in Germany and its belated acceptance in England and France have had profound consequences in the economic and political destinies of Europe.

The influence of the *Verein Deutscher Ingenieure* must be ranked among the major forces in the upbuilding of both the technical universities and the *realschulen.* The *Verein* had its origin in a student association at the *gewerbe-akademie* of Berlin and developed into a national organization as graduates formed branches for mutual aid and education in the chief industrial centers. At the chief meeting of the *Verein* in 1864 its first director Professor Grashof, then the Rektor at Karlsruhe, made an extended report on the polytechnic schools which contained many prophetic recommendations. He advised the consolidation of the special schools of mining, building and industrial technology at Berlin into a polytechnic school, recommended that the training of foremen and technicians be handed over to a distinct group of schools and urged the polytechnic schools to take on completely the character of technical universities, training men for the highest ranks of state and industrial service and as teachers in the technical and secondary schools. He pointed out that standards are primarily determined by admission requirements rather than the length of the course and advised that the preparation for higher technical studies should be given in an *oberrealschule* or *gymnasium* rather than a trade school. He disapproved of a break in the middle of the course for a period of industrial practice and recommended a year of such experience before admission. The Grashof report fixed the educational policy of the *Verein* for many years. Virtually all its major recommendations have since been adopted. A comparison of this report of 1864 with the address of Sir John Fowler in London in 1866 and with the Morrill Act of 1862 in the United States shows most effectively the contrast in the status and attitudes of the three nations at this middle period.

The unremitting pressure of the *Verein* was a major factor in winning full university privileges for the *hochschulen.* In equal measure it fostered the *realschulen* and contended for the equality of scientific and classical education. Its initiative was effective in 1902 in securing the removal of shop instruction from the *hochschulen* and the substitution of a year of required industrial experience. The *Verein* also took the lead in 1908 in bringing together all the major professional and industrial groups in the formation of the *Deutscher Ausschuss für Technisches Schulwesen,* or central committee on technical education. This body, widely known by the abbreviated title of *Datsch,* has rendered notable service in educational guidance, in formulating methods of training and compiling means of instruction for apprentices, advising on curricula for trade schools, in clarifying the relations of all types of technical schools in the educational system and in fostering their relations with the industries. Its annual conference on *hochschulefragen* has become the principal forum on the common problems of the technical universities. The *Verein* has sponsored many researches at the *hochschulen* through money grants and has afforded the principal channel for the disclosure of the results. Its publications on educational matters probably equal those of all the engineering societies of France, Great Britain and America combined.

The rising prestige of the *hochschulen* as a result of the support of the profession and the evidences of imperial favor won for them the backing of the new generation of industrial magnates. A brilliant example of the research institutes established by industry was set by the Kaiser Wilhelm Institute of Metallurgy at Aachen, representing a gift of $400,000 from the Krupp interests. It was largely through industrial pressure that Prussia was led to establish the two most recent hochschulen at Danzig and Breslau.

Relations with the Universities.—The rise of the *technische hochschulen* apart from the universities proper has been both praised and deplored. Viewed in historical perspective it appears as an almost inevitable result of tradition and circumstance. Had there been time for a slow assimilation of the new discipline it seems probable that technical education would have found its place in the university system, but Germany began late and the march of events was too swift for institutions bound by conservative traditions. Engineering had to fight its way up from handcraft, held in low esteem by the privileged classes. It had to win recognition as a profession against a strong spirit of guild exclusiveness nurtured in the gymnasium and university, which held a monopoly of entrance to all higher professional and state careers. Most of the universities were situated in the small provincial towns, while the polytechnics arose in the capital cities under the direct nurture of the states. To German thinking a country college is no place for an engineering school. The universities enjoyed an autonomy which made it difficult for state officials to use them for such specific ends as the training of technical functionaries and the assistance of industry. University traditions exalted "pure" or abstract learning as something far above matters of practical interest and largely disregarded the interrelations of subjects, so important in the effective training of an engineer.

The advance from the status of a *polytechnikum* to that of a *hochschule* had a symbolic significance which it is difficult for an American, accustomed to apply the term "university" indiscriminately to a Harvard, a city Y. M. C. A. and a correspondence school, to appreciate. The term *hochschule* in its modern sense is inclusive of all institutions having equal rank with the universities. It applies to institutions preparing for the recognized professions and appending to the ministry of education rather than that of commerce. It carries with it autonomy of internal organization and the prized privileges of *lehr- und lern-freiheit.* It implies admission by the maturity certificate of the secondary schools. Far from least in importance, it fixes the status of the professors in the most preferred class of state officials.

The spirit of rivalry between the universities and *hochschulen* acted as a spur to both groups. The desire for recognition of complete equality with the universities led the polytechnics to pattern their organization after the universities as closely as the nature of their work would permit; it became a powerful unifying and standardizing influence; it led the schools to make a close alliance with the profession and the industries; and it led them to make common cause with the *realschulen.* A strong party in the technical schools stood for amalgamation with the universities; an equal group stood for complete separation, with the recognition of equal privileges. The right to award the title of engineer and the doctorate became the pivotal issue. The Swiss Polytechnic at Zurich had the former privilege long before any of the German school. When young engineers and chemists worked beside a "*herr doktor*" from a university they were often made acutely aware of an inferior status. Without the right to confer the doctorate there was little chance for the general scientific departments of the *hochschulen* to attract advanced students and to prepare men for teaching positions.

The issue between the party of amalgamation and the separatists was especially acute in the 90's, but was settled for the time by the Emperor William II in person when, at the centennial celebration at Charlottenburg in 1899, he officially bestowed the privilege of granting the degrees of *diplom-ingenieur, doktor-ingenieur* and *doktor honoris causa.* With the following words he silenced all controversy:

> "In the relations of the *technische hochschulen* to the other highest educational establishments there is no opposition of interests and no other competition than this, that each of them and every member of them for his own part should do full justice to the claims of life and science, mindful of the words of Goethe

> 'Neither be like to the other, but each be like to the highest.
> How is this to be done? Let each be complete in himself.' ''

In the republican Germany of today the issue of unification has arisen anew and it is not improbable that the next decade may see the creation of one or more universities with faculties of technical science.

Changes of the Last Fifty Years.—The nature of the curricula of 1833, 1850 and 1863 has been indicated in the sections devoted to Karlsruhe and Charlottenburg. After 1870 the outreach for university privileges tended to draw the programs of the several institutions toward a common norm. The desire to facilitate the migration of students from one school to another acted in the same direction. With the advance of preparatory education in the *ober-realschule* to a level of equality with the *gymnasium* the technical schools laid aside their narrower disciplinary methods of teaching and adopted the freer methods of the universities, but subjects were taught in a less abstract manner and with far greater interconnection. Project teaching which threw the student on his own responsibility came to be especially emphasized in the technical courses of the higher years. Laboratory teaching in engineering subjects was introduced into most of the German schools at a relatively late period, although there were extensive mechanical laboratories at Munich as early as 1870. American example had a powerful influence in the development of teaching laboratories, through the report of a commission which visited leading schools in the United States after the Congress of Engineering in connection with the Columbian Exposition of 1893. Previous to this time most of the schools had only private research laboratories which had been installed on the initiative of individual professors. Charlottenburg alone spent $900,000 in installing teaching laboratories between 1893 and 1897. Internal instruction in shop practice had been given in many of the *hochschulen* before 1900 in order to compensate in some measure for the lack of industrial experience by the students. Reference has already been made to the initiative of the *Verein Deutscher Ingenieure* in securing the abandonment of shop teaching. It is worthy of note that a number of German professors of engineering who inspected American schools in 1893 expressed strong disapproval of much of the shop instruction they had seen. Before 1900 many of the curricula had been three years in length, but at that time practically all were placed on the uniform basis of four years.

The technical universities have offered an increasingly wide range of instruction in recent years outside of strictly scientific and technical fields. There has been no attempt to encroach on the functions of the universities, but rather to broaden the training for technical professions on the humanistic side, especially in the realm of political and social studies. As one eminent *rektor* put the case:

> "Technical education designed exclusively to meet the demands of a special occupation would isolate the technicist from the civic life by which he is surrounded and would alienate him from the ideal interests of society."

There is now a growing tendency to introduce the teaching of industrial organization and management, including the new division of psychotechnics.

The expansion of research activities has been especially marked since the right to confer the doctorate was granted in 1900. The German technical university of the present is far more than a teaching institution—it is the major creative agency of the nation for the advancement of all technical sciences and arts. The high importance of this role in the national life is well epitomized by the motto of one of Germany's great technical societies, *"Die Technik ist Deutschlands wirtschaftliches Schicksal"*—technical science is Germany's economic destiny.

D. SWITZERLAND

The Swiss constitution of 1849, which was designed to strengthen the Confederation after a severe economic crisis, gave it the right to establish a Federal Polytechnic School and a university. Hitherto all public responsibility for education had been vested in the several cantons. Thriving technical schools of a practical character had been built up under cantonal auspices. A special school for industry, public works, building and the arts was founded privately in 1853 by five professors in Lausanne on a plan resembling the *Ecole Centrale* of Paris. About twenty years later it was taken over by the Canton of Vaud and became the present *Ecole d'Ingénieurs* of the University of Lausanne, serving principally the French speaking area.

The founding of the Federal Polytechnic School may be ascribed to the feeling that only the highest grade of scientific direction would enable Switzerland, a country of crowded population but largely devoid of raw materials, to maintain its industrial position in the presence of its larger and more generously endowed neighbors. The School was established at Zurich in 1854. The city supplied it with an admirable building and with much of its original equipment, while the Confederation made an annual subvention of 250,000 francs toward its operating expenses. This was a large sum for the times. The Polytechnic had no hampering traditions and was free to profit by the experience of the earlier schools of France and Germany. By leaving all preparatory and vocational education to the cantonal schools, it was able to place its whole program on a professional plane equal to any university. Furthermore it had the right, not then possessed by any German institution, to confer the professional diploma of engineer. The Polytechnic brought together a staff of notable qualifications and soon attracted students from all parts of the world. Without doubt it exercised a strong influence on the early development of engineering education in Italy and on the later evolution of the *hochschulen* of Germany and Austria.

E. THE UNITED STATES

Origins and Characteristics.—Engineering education in the United States is the outgrowth of a popular movement early in the last century to promote "the application of science to the common purposes of life." There was no thought in the beginning of creating any formal discipline for the profession of engineering, the aim was rather "to give farmers and mechanics such a scientific education as would enable them to become skillful in their professions." Rensselaer had scarcely begun its pioneer work as a school of practical science when the advent of the railroad opened a new chapter in the history of American engineering. The engineers of the earlier decades, a scattered group of land surveyors, builders of roads, canals and bridges, and practical constructors of machinery, had been largely self-taught. With the railroad came a demand for engineers with a greater mastery of the scientific resources of the art. There was no foundation for a scheme of training by pupilage, as in England, and the engineering school arose by simple necessity. Models were borrowed from France, where higher technical education was highly developed, and the effort to apply science to the common purposes of life passed rapidly into the special form of a professional discipline for engineers. This in turn was quickly assimilated into the newly developing university system.

The leaders of the early years were not statesmen nor active practitioners, but scientists and educators. In their hands engineering education acquired its traditional freedom from outside regulation. The consequences of the early fixation of technical education as a professional discipline on the university level have not been wholly good. Engineering colleges have been multiplied in America as in no other land, but other types of technical schools have been largely eclipsed. The training of artisans, foremen and technicians, and possibly of the higher officers of industrial production as well, has been neglected in favor of the training of professional engineers. A democratic desire to give "all of the boys a chance to get to the top" has resulted in indefiniteness of aim and failure to make a rational division of the functions of technical education among different types of schools. Measured by an international scale the chief virtue of American engineering education is probably its accessibility, its chief defect vague objectives and uncertain standards.

The Period of Germination.—The War of Independence threw the new-born American states back on their own economic and intellectual resources. It was a pioneer age, when men prized versatility above specialized training and practical resourcefulness above the refinements of science. Inventions multiplied and industries developed in the hands of ingenious mechanics. A handful of engineers trained abroad and a few self-taught Americans executed the simple public works. A little coterie of intellectuals who had come under French influence, Franklin and Jefferson among them, visioned the possibilities of science and labored for its advancement, but the established colleges of the day held fast to the exclusive classical traditions brought over in the early colonial period from Cambridge and Oxford. Efforts for the practical use and advancement of science came largely from popular sources, from groups of merchants and mechanics who formed institutes, founded libraries and offered premiums for inventions and for improvements of process or design.

A glance at the educational conditions of 1800 will show how impossible it was for applied science to become rooted in the existing educational system. A bare half dozen of the twenty-one colleges had made any provision whatever for the teaching of the physical sciences and that against the open hostility of the ruling academic party. There was no extended system of secondary education and the scattered Latin and grammar schools were entirely dominated by the classicists. Professional schools of law, medicine and divinity were just beginning to displace the more casual training by pupilage. A system of university education, in its modern comprehensive sense, did not exist. Tradition left virtually the entire field of education to private, sectarian or local initiative. To make science an effective aid to production a new type of school and a new type of teacher were needed. While colleges and public authorities remained deaf to the rising chorus of demand for practical scientific information, it remained for men of affairs to take an effective initiative.

Pioneer Efforts.—The earliest American effort to create a school of practical science was made in 1821 by R. H. Gardiner and a group of fellow townsmen of Gardiner, Maine. Aid was obtained from the state legislature in establishing the Gardiner Lyceum

> "to give farmers and mechanics such a scientific education as would enable them to become skillful in their professions."

Gardiner enlisted the aid of a young Bowdoin tutor, Benjamin Hale, who had turned from theology to science and who threw himself into the work of organizing the school with missionary zeal. The school was opened in 1822 with a two year course of instruction. In 1824 Hale reported to the backers:

> "The winter classes are already established in surveying, in navigation, in carpentry and civil architecture, and in chemistry."

Hale's addresses in quest of financial support show plainly that he foreshadowed the modern schools of technology. Unfortunately the times were not ripe. Legislative aid was withdrawn and the school faded out. Hale went to Dartmouth and was largely influential in laying foundations for its later work in the Chandler Scientific School.

This effort at Gardiner was not an isolated event. Stephen Van Rensselaer of Albany, land owner, capitalist and leader in public affairs, took steps in 1823 to establish a school at Troy

> "for the purpose of instructing persons who may choose to apply themselves in the application of science to the common purposes of life. My principal object is to qualify teachers for instructing the sons and daughters of farmers and mechanics, by lectures or otherwise, in the application of experimental chemistry, philosophy and natural history to agriculture, domestic economy, the arts and manufactures."

The genius behind this proposal was Amos Eaton whom Rensselaer had employed to make certain surveys and by whose scientific capacity and practical sagacity he was deeply impressed. As a lawyer, civil engineer, geologist, botanist, chemist and educational pioneer, Eaton combined a Baconian versatility in science with a Yankee's capacity for practical affairs. Under the direction of Eaton the Rensselaer School, as it wa first known, developed in the course of twelve years into a professional school of civil engineering, the first in the English-speaking world.

An organization of citizens of Philadelphia brought forward in 1826 a plan for a polytechnic and scientific college, which should not require Latin and Greek for entrance and should give instruction

> ''in every branch of knowledge requisite for the agriculturist, the mechanic or manufacturer, the architect, the civil engineer, the merchant and other man of business''

but the project led to no tangible result.

The First Engineering Schools.—The Military Academy at West Point rightly claims the place of seniority among the American schools of applied science. Its beginnings are uncertain. Originally a corps of engineer cadets and scarcely more than a name before 1812, it began to emerge as a school of advanced character when Col. Sylvanus Thayer became Superintendent in 1817. Thayer had made a study of the military schools of Europe and the program and regime which he introduced plainly show the influence of the *Ecole Polytechnique* of Paris. Chemistry, physics, higher mathematics and descriptive geometry were taught and engineering applications were considerably developed.

While the Rensselaer School continued for many years to fulfill the purposes of its founder by training teachers of natural science and left a great impress in that field, its chief work passed rapidly into the realm where it won its great renown, that of civil engineering. Instruction in engineering made its way into the curriculum at Rensselaer by gradual stages. The courses of 1825 included ''land rveying, mensuration, measurements of the flow of water i rivers and aqueducts.'' The following year there appeared ''hydrostatics and hydrodynamics'' and ''calculations upon the application of water power and steam.'' In 1827 reference was made to ''land surveying and general engineering.'' The term ''civil engineering'' appeared first in the catalog of 1 28. In 1835 there was a distinct program of instruction in "engineering and technology" and the degree of Civil Engineer was bestowed for the first time on a class of four. The course of study in this early period occupied a single year. There are indications that Eaton visualized a graduate school for men who had previously completed a liberal education. While this ideal was never fully realized, the students were mature and there was a goodly proportion of college graduates among them.

The Rensselaer Polytechnic Institute.—Amos Eaton left his impress on engineering education principally through his disciple and successor, B. Franklin Greene. Upon succeeding Eaton as Director in 1846, Greene undertook a complete reorganization of the school. He visited leading institutions of Europe and analyzed their curricula in the search of models. On his return he proposed a plan for a comprehensive polytechnic institute which would deal "with all matters cognate to architecture and engineering" and at the same time continue the original work of the Rensselaer School in training teachers of natural science. Without doubt Greene was the first man in America to submit the problems of education for the technical professions to thorough investigation and analysis. In essential matters his conclusions remain sound today. What he visualized was an educational discipline complete in itself, not narrowly utilitarian but "adapted to the complete realization of true educational culture."

Greene, more than any other man, gave to engineering education in America its distinctive form and character. The plan for a group of "schools" to prepare for all the technical professions which Greene had projected was beyond the means then available. In consequence only the branches of civil and topographical engineering were at first developed. The name Polytechnic Institute which was adopted in the reorganization of 1849 signalized the ascendancy of professional training for engineering over the original aims of the school. Greene found his models in the highly developed technical schools of Paris. The new curriculum followed the general plan of that of the *Ecole Centrale des Arts et Manufactures.*

A comparison of the Rensselaer curriculum of 1850, as shown below with that of *Ecole Centrale* of the same period, as shown on page 765, indicates that Greene borrowed more from the form than the content. The distinguishing feature was the parallel sequences of humanistic studies, mathematics, physical sciences and technical subjects which have marked American engineering curricula to this day. Experience soon showed that the new curriculum of three years was in advance of the prevailing preparatory education. To close this gap a "preparatory division" of one year was then provided, but the distinction of name gradually disappeared, leaving the integrated four-year program which has since become the widely accepted norm.

RENSSELAER CURRICULUM IN CIVIL ENGINEERING, 1849–1850

Year I	Year II	Year III
English	English	English
Foreign language	Foreign language	Philosophy of mind
Algebra, geometry, trigonometry	Analytics, calculus	Mechanics
Geometrical drawing	Descriptive geometry, machine drawing	Descriptive geometry, perspective, topographical drawing, stereotomy
General physics	General physics	Industrial physics
Botany	Chemistry	Metallurgy
Surveying	Zoology	Practical geology
	Mineralogy	Mining
	Geology	Geodosy—trigonometrical, railroad and mine surveying
	Topographical and hydrographical surveying	Machines
		Constructions — theory of structures, bridges, hydraulic works, railways

Assimilation by the Universities.—The example set by Rensselaer was soon followed by other institutions. Union College introduced the teaching of civil engineering in its scientific department in 1845. Dartmouth established the Chandler Scientific School in 1851, intended by its benefactor "to be a school of the industrial vocations." The University of Michigan, the pioneer among the state universities of the nearer and farther West, began instruction in engineering in 1852. Michigan owes much to the foundations laid by DeVolson Wood, a former country school master who had worked his way through Rensselaer by teaching in the preparatory division. On receiving his degree of Civil Engineer in 1855, Wood decided to locate in Chicago. He stopped off quite casually on his way west to have a look at the University of Michigan. A newly appointed professor of civil engineering had failed to appear and the authorities were in a quandary. Wood was asked to stand by for a few days as a stop-gap and he remained seventeen years. Brown was also early in the field. One of its first engineering graduates, R. H. Thurston, C.E., 1859, later became a dominant figure in mechanical engineering through his teaching at Stevens and Cornell and his many researches and publications.

Harvard and Yale both took steps to create schools of applied science in 1847. Through the influence of Prof. Eben N. Horsford, a Rensselaer graduate who had worked with Liebig at Giessen, Abbott Lawrence was led to establish the Lawrence Scientific School at Harvard. His gift of $50,000 for this purpose is said to have been the largest yet made to an American college by a living donor. It seems that Lawrence had clearly in view the establishment of an engineering school. His letter of instruction enjoined that

> ''The three great practical branches to which a scientific education is to be applied are: 1st, engineering; 2d, mining in its extended sense, including metallurgy; 3d, the invention and manufacturing of machinery.''

It was a long period before Lawrence's purposes were adequately realized at Harvard. Aggasiz the naturalist and Horsford the chemist became the first professors of the new school. Their interests lay in other directions and the college as a whole was openly hostile to technical studies. The first engineer was graduated in 1854 and there were few others before 1860. In the first forty-five years of its history the Lawrence Scientific School graduated but 155 engineers in all. It was not until 1892 that the teaching of engineering was developed with vigor at Harvard. Harvard's tardiness in realizing Lawrence's intentions appears to have been a major factor contributing to the establishment of the Massachusetts Institute of Technology on an independent foundation in 1860.

Applied science at Yale owes much to the early inspiration of Prof. Benjamin Silliman, who began his long and fruitful career in 1801. Two chairs of applied chemistry were established in 1847 as the nucleus of a department of "Philosophy and Arts" directed by Prof. John P. Norton. The chair of mathematics and civil engineering was created in 1852 and the chair of metallurgy shortly after. In 1856 a three-year course in civil engineering was in operation and a course in mechanical engineering—the first in America—existed on paper. The scientific school was severely handicapped by lack of funds and by the avowed hostility of "the college proper." Its prosperity increased rapidly after 1860, when Joseph E. Sheffield came forward to give it a home, an endowment of $100,000 and the name Sheffield Scientific School.

The Turning Point.—The period leading up to 1860 had been one of difficult pioneering. Practical men—Franklin, Jefferson, Gardiner, van Rensselaer, Lawrence, Chandler, Sheffield—grasped the economic possibilities of science and technics while the great body of educators remained hostile or aloof. How often "the children of this world are wiser in their generation than the children of light"! There could be no large development until the monopoly of classical learning was broken, nor could this come until the early conception of the nature and objects of education and of its relations to the state had been profoundly altered. By 1860, thanks to the work of Horace Mann and other pioneers, foundations had been laid for a comprehensive system of public education on advanced lines. The Morrill Land Grant Act of 1862 was symbolic of this deep change of public attitude. Morrill's first bill had been vetoed in 1857 through the opposition of the states' rights party, but the Congress of 1862 was a northern body, pledged to the cause of farmers and mechanics, and ready to put the resources of the Federal government behind the popular movement "for the application of science to the common purposes of life" which had been gathering momemtum from the days of Gardiner and van Rensselaer. The impetus of the Morrill Act was felt by private as well as public institutions. In the space of a single decade, from 1862 to 1872, the number of engineering schools increased from six to seventy, a rate of expansion without parallel.

Leaders in the Period of Expansion.—It was a fortunate circumstance that this period was ushered in by the establishment of three notable institutions which helped to supply men and models for the many others soon to follow. The Massachusetts Institute of Technology was largely the creation of William Barton Rogers, an educator and geologist of note, who secured the backing of a group of influential citizens of Boston and the financial aid of the State in a broadly conceived plan

> ''for the purpose of instituting and maintaining a society of arts, a museum of arts and a school of industrial science, and aiding generally by suitable means the advancement, development and practical application of science in connection with arts, agriculture, manufacture and commerce.''

The Society of Arts, intended for the popular diffusion of scientific knowledge, began its work in 1862. The opening of the school of industrial science was delayed by the war until 1865. The museum yet remains to be established. The name ''Technology'' was proposed by one of the original backers, Dr. Jacob Bigelow, to mark the distinction of purpose from the pursuit of science as a form of ''polite learning.'' The Institute has been the broadest in its scope of any of the American schools of applied science, embracing architecture, biology, chemistry, physics, geology and naval construction in addition to the several branches of engineering. In its size and scope it has resembled the great technical universities of Germany more closely than any other American institution. One of its notable contributions to the early history of engineering education was the introduction of individual laboratory instruction in the physical sciences.

The iron and coal industries of the middle states and metal mining in the West began to develop rapidly about 1850. The mineral industries were mainly dependent on Europe for men of scientific training and the *Bergakademie* at Freiberg counted many Americans among its students for several decades. Professors Chandler and Joy, chemists, and Eggleston, metallurgist, took the principal initiative in creating the first American school of mines at Columbia in 1864. Chandler is said to have adapted the original plan of studies from the *Ecole des Mines* of Paris; the curricula of both schools covered a period of three years and consisted wholly of scientific and technical studies. At a later period the School of Mines lengthened its program to four years and broadened it on the humanistic side. Columbia supplied the prototype for most of the schools of mines and metallurgy which sprang up in the period between 1865 and 1880.

The Morrill Act opened the way for the rapid expansion of engineering education throughout the North and the West. Within a period of twenty years the federal government made grants from the public domain which considerably exceeded the area of Great Britain to aid the states in establishing colleges of agriculture and the mechanic arts. One of the most influential of the early land grant institutions was Cornell University, intended by its founder and chief benefactor to be "an institution where any person can find instruction in any subject." Cornell, though essentially an independent institution, received the land grants of the State of New York under a liberal policy which encouraged the older and the new educational disciplines to develop on even terms.

There seems to have been a good deal of confusion in the early land grant colleges as to the character and purposes of the schools of "mechanic arts." Andrew D. White, Cornell's first president, probably did more than any other one person to establish the interpretation which has since widely prevailed. When Cornell opened its doors in 1868 some of the trustees advised making the school of mechanic arts a manual labor college of inferior rank. There was a small waterpower on the campus which they proposed to use in operating a manufacturing plant employing student labor. President White thought otherwise. What he visualized by education in the mechanic arts was a training "in every way equal to the learned professions." He visited Europe and made a close study of technical education. On his return he sought out men of distinction like Morris and Sweet for the professorships, personally raised funds and purchased the first equipment for the engineering shops, and later brought Thurston from Stevens to carry on a great constructive work in mechanical engineering. The influence of Cornell in the period of the great growth of the engineering colleges in enrollments and resources, extending from 1870 down to 1900, both by direct example and through her many graduates who went out as organizers and teachers, is one of the most notable of the recent chapters in the history of American higher education.

1870 as a Transition Point.—The year 1870 marks the boundary between two quite distinct periods of development. The earlier or formative stage had been marked by the creation of new and distinctive schools and programs; its dominating personalities were more often scientists and publicists than engineers; and its chief aim had been the training of civil engineers to meet the problems of an era of rapid geographical expansion and of growth in urban population. After 1870 came a period of expansion and ramification, based on the models already created; engineers of distinction took an increasing leadership in education; an American literature of engineering began to develop through the authorship of leading professors; the engineering profession took on solidarity and began to influence the scheme of education; and an extraordinary expansion of industry created a wide field for mining, metallurgical and mechanical engineers.

There was also a marked change of educational method in this transition period. In the earlier years there had been little laboratory teaching; practical exercises in the drafting room and the field, together with occasional demonstrations by teachers of the sciences, sufficed to round out the didactic teaching of the class-room. The most noteworthy feature after 1870 was the great development in laboratory methods of teaching, a field where American leadership has been especially marked. Rogers had projected laboratories for physics, manipulative and analytical chemistry, metallurgy and mining, and industrial chemistry in his plan for the Massachusetts Institute of Technology. With the aid of his associates Pickering and Eliot the laboratory teaching of the physical sciences was placed on a sound basis in 1869. The first engineering laboratory in America was doubtless that established by Thurston at Stevens Institute in 1871. Thurston went to Cornell in 1885 and was largely instrumental in building up the engineering laboratories there. His influence on the development of curricula and methods of teaching in mechanical engineering probably exceeded that of any other American educator.

The early American mining schools were established in eastern centers and suffered from the handicap of being remote from the chief seats of the industry. The German mining academies at Freiberg and Clausthal were located in important and varied mining areas and had worked out an intimate combination of teaching and actual contact with mining operations. Paris had achieved an approximate equivalent through the required *stages* to which its students were assigned in the vacation periods. The London school did its work under government regulations which required the students to spend a certain period as active miners before they could receive their diplomas. The American schools sought to meet this handicap by installing mining laboratories in which the actual operations of the industry were simulated as closely as possible. Professor Runkle is said to have conceived the plan of such a laboratory for the Massachusetts Institute of Technology when conducting a scientific expedition to the Rocky Mountains in 1872.

The Development of Shop Instruction.—The early courses in mechanical engineering were concerned chiefly with the design of machinery and with the technology of the workshop. The problems of power production and application on a large scale did not begin to assume a major importance until the 80's. The shops rather than the laboratory were the seat of the early efforts at practical instruction. Worcester Polytechnic Institute began its work in 1868 with a small manufacturing plant on the premises, in which the students worked with practical journeymen in commercial production. The original purpose of the school, that of training mechanical superintendents, was preserved for twenty years, after which the school became a general college of engineering. During that period more than a quarter of the required work was devoted to shop practice. The Cornell shops, which had a wide influence in fixing the general norm among the land grant colleges, were installed in the early 70's solely with a view to instruction. The influence of President White and of Professors Morris and Sweet has already been referred to on page 818. Shop practice was first mentioned specifically in the Cornell catalog of 1874–75 and was then included in each of the twelve terms of the course. Shop work was still required through the entire course in 1898, but by 1915 the requirement had been reduced to five semesters. Thurston was evidently greatly impressed with the system of shop training he found in operation when he came to Cornell in 1885, for he wrote:

> ''The progress which can be made by the skillful application of the system of graded exercises is simply astonishing to one who has not seen it in operation; and it is probably well within bounds to assert that, by means of this method, the young aspirant can be carried further along in his trade in a year, than by the old methods and lack of system in apprenticeship he could go in the whole period of the seven years for which it was once customary to write the indenture.''

It is interesting to note that Frederick W. Taylor of scientific management fame severely criticized that statement and thought it would be more appropriate to reverse the ratio. The methods of shop instruction introduced at the Massachusetts Institute of Technology owed much to the exhibit of the Russian school shops at the Centennial Exposition of 1876.

The Trend toward Scientific Training.—The early emphasis on shop-work was symptomatic of the urge which the schools felt to make their training as practical as possible. The acceptance of formal education by the profession and the industries was not won without a long struggle. Traditions carried over from pioneer days and reinforced by British example and influence kept alive the distrust of theory and emphasized its detachment from practice. The early discussions of engineering education in the technical press and by the engineering societies abounded in criticism of this nature. Engineering teachers felt the call to demonstrate their competency by undertaking collateral practice. A strong scientific spirit and zeal for research were slow to develop in many of the colleges. With the opening up of the field of electrical engineering in the 80's followed by that of chemical engineering in the 90's, there was a distinct swing away from the effort to make engineering education as practical as possible in the direction of making it more scientific. Most of the earlier teachers of electrical and chemical engineering had not been trained as engineers but as physicists and chemists. Through this process of assimilation engineering was enriched and fertilized with a scientific spirit. Toward the end of the century there was a perceptible gain in the volume and quality of research activity. In the same period the educational process began to lose some of its earlier character of a fairly self-contained professional discipline and to take on that of an introductory stage of scientific formation. This movement was greatly advanced by the close bond between the schools and the newer industries which had developed directly out of scientific research and technique and notably the electrical industry. An understanding arose, almost from the beginnings of the industry, under which the employer assumed practically the entire responsibility for the practical training of the student and the college was left free to devote itself to the scientific foundations.

Contemporary Movements.—Since the turn of the century three movements have stood out with special prominence. The first is the upbuilding of the cooperative system, instituted by Dean Herman Schneider at the University of Cincinnati in 1906, which has been discussed at length in Bulletin No. 12 of this series. The division of the student's time between instruction and practice in practically equal periods is not new, as the sandwich system has been in use in Scotland for more than fifty years, but the provision of regularly scheduled intervals of periods of instruction in college and of supervised and correlated experience in industry was an essentially original feature. The second movement has been the greatly increased emphasis on the economic and management phases of engineering under the inspiration of the pioneer work of Frederick W. Taylor and his followers. This movement has reached such proportions that the question has been raised whether the major function of some, if not all, of the engineering colleges should be to train men for industrial management rather than the technical work of engineering. The third outstanding movement has been a great increase of engineering research and post-graduate study. Prior to 1900 there were almost no graduate students of engineering; the doctor's degree in engineering was seldom earned; engineering teachers devoted such free time as they could command to collateral practice; authorship was largely a process of compilation and editing; and the engineering schools had little direct share in the advancement of the art. The movement toward creative activity in engineering schools still lags far behind its chief examples and sources of inspiration, the industrial research laboratories of America and the technical universities of Germany, but its progress has been noteworthy.

Guiding Influences.—The American system of engineering education is a complex of borrowed and indigenous elements: the collegiate plan of organization and most of the traditions of the professoriate can be traced back to the earlier arts colleges and the older universities of England; the emphasis on interrogatory rather than expository forms of teaching goes back to the old English grammer schools; early engineering curricula were derived from French models; from France also came the professional school of engineering rather than the British scheme of pupilage; Russia supplied early models for the teaching of manual arts; and German research ideals and methods have made a profound impress in recent years.

The genius of the American schools has been more adaptive than creative, but in two respects at least they have exercised a conspicuous leadership—the introduction of individual methods of laboratory instruction and the provision of distinctive training in the economic and management phases of engineering.

In no other country have the engineering schools been so free from outside domination. They owe little to statecraft other than the provision of means for their extension and support. They owe little to the organized engineering profession except the benefits of occasional criticism of their aims and methods. They owe little to the industries except an ever-widening field of employment for their graduates. To a striking degree, these schools have been left to work out their own destiny and to fend for themselves. This has been the source of both strength and weakness. There has been complete freedom for educational experimentation and innovation which, when exercised, has justified itself abundantly through a number of major advances. On the other hand the leaving of all initiative to individual institutions, with no coordination of policy, has resulted in failure to work out a well-rounded national system of technical education in its several natural divisions.

The engineering school has remained largely a thing apart, a seat of individual effort and of individual discipline, and has not achieved in America as in Germany a large place in the strategy of social progress. Is this its destiny? No doubt the engineering school will long remain primarily a teaching institution and a place of research for inquiring minds; enlightened and inspired individuals will be its most precious gift to society; but it is scarcely conceivable in an essentially technological civilization that the school of technical science should be content to remain almost wholly a transmitting medium, with only a minor share in the creation of knowledge and with little or no share in the shaping of social institutions.

PART II. ENGINEERING EDUCATION IN FRANCE

A. The National Educational System

Its Dual Character.—France has two distinct systems of education, each complete in itself. One is designed to transmit a cherished cultural heritage and to form an intellectual elite for the future leadership of the nation. The other prepares for citizenship at large through a substantial base of general knowledge and a superstructure of vocational training. The secondary schools, known as *lycées* and *collèges,* together with the universities and special professional schools, make up one system; the primary schools, vocational schools, higher primary schools and the higher schools of mechanic arts, make up the other. Each system has its own group of higher technical schools, the one preeminently professional in

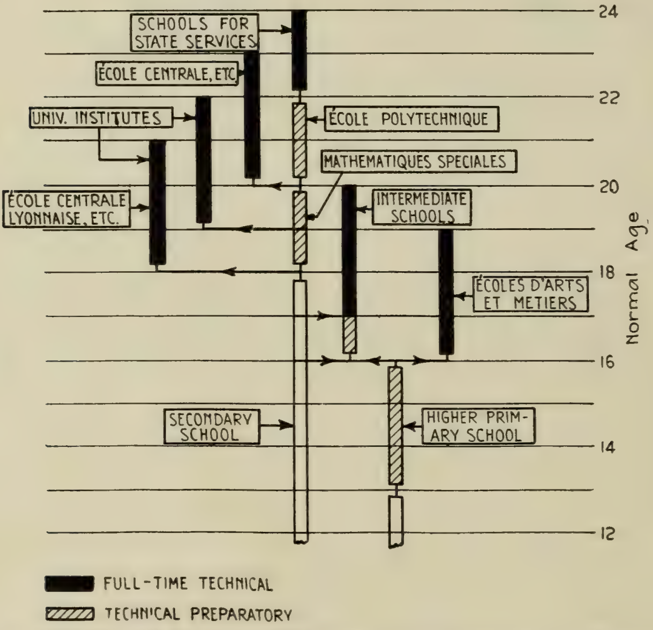
SCHOOLS FOR STATE SERVICES
ÉCOLE CENTRALE, ETC
UNIV. INSTITUTES
ÉCOLE POLYTECHNIQUE
MATHEMATIQUES SPECIALES
ÉCOLE CENTRALE LYONNAISE, ETC.
INTERMEDIATE SCHOOLS
ÉCOLES D'ARTS ET METIERS
SECONDARY SCHOOL
HIGHER PRIMARY SCHOOL
24
22
20
18
16
14
12
Normal Age
FULL-TIME TECHNICAL
TECHNICAL PREPARATORY

Fig. 1. Technical Schools of France in the Systems of National Education.

spirit and intellectual in emphasis, the other preeminently industrial and practical. A small group of engineering schools occupy intermediate ground.

The cleavage between the two systems is partly traditional and partly logical. French secondary and university education is an outgrowth of the classical and philosophical disciplines of the middle ages, to which modern studies have been joined in recent decades. It has never been conceived as a popular system but rather as a special medium of cultural transmission and of preparation for the intellectual professions. The primary system is almost wholly the work of the past century. The French have pushed the principle of distinct forms of preparation for intellectual pursuits and for practical pursuits further, perhaps, than any other Western nation. The actual line of demarkation between the two systems is largely social and financial. Families which can afford the tuition fees, and in many cases the cost of *pension* as well, send their children to a national *lycée* or a municipal *collège;* those who cannot, patronize the gratuitous *école primaire;* as a result the secondary schools serve about one-tenth of the population. There are bridges between the two systems at certain stages and the State maintains a considerable number of *bourses* to enable the more gifted youth to pass over from the primary to the secondary system. As one educator expressed the situation, "France assumes that her social stratification forms on hereditary lines and looks for exceptions in proportion to the Mendelian ratio."

Conflict of Ideals.—The conflict between the old tradition of a stable society with its cultural aristocracy and the newer ideals of social democracy has made the educational system a battle ground in recent decades. The rallying cry of the radicals is *"L'école unique!"*—a single national system freely open to all classes. The intellectuals, proud of the national culture and solicitous for its future, ardently defend the present dual system. The privileged classes have no desire to lose their present monopoly of favored careers. The clerical party protests unceasingly against the existing policy of secularization. The intensity of this interest, fanned by constant agitation, makes any amelioration very difficult. At the moment the first four years of the two systems are being unified, but further amalgamation seems very remote.

Organization of Secondary Education.—The *lycées* and universities of France are essentially one continuous system under common direction, often referred to in its entirety as "the University of France." The *lycée* has the function of general education or, in the French phrase, *la formation de l'esprit;* the university faculties are devoted to the pursuit of special intellectual interests. The goal of secondary studies is the *baccalauréat,* a degree awarded by the State to mark the completion of general education and the right of admission to the universities. The professors in the *lycées* and the university faculties have the same status, that of *professeur de l'université,* and must meet the same qualifying standards. Both groups are equally cultivated and scholarly men, but the more gifted teachers gravitate as a rule to the *lycées* and the more creative scholars to university chairs. Both posts are paid alike and while the salaries are modest the places are eagerly sought by the best minds in France.

A reform introduced in 1902, following an intense struggle between the partisans of classical and of modern studies, was intended to place them on a basis of complete quality and to facilitate transfers from the primary to the secondary system. To these ends the curriculum was arranged in parallel options and divided into a sequence of cycles. First come four years of *classes enfantines* with a single program, now in process of unification with the primary schools; then follows the *premier cycle* of four years with two parallel options, classical and modern; finally, there is a *deuxième cycle* in two parts, two years with four parallel options—Latin and Greek, Latin and modern languages, Latin and sciences, and modern languages and sciences—leading to the first part of the baccalaureate, and a final year of concentration with two options—philosophy and mathematics—leading to the complete baccalaureate. The examinations of the baccalaureate are set and judged by a jury of university professors and are partly written and partly oral.

Secondary Curricula.—The curricula are prescribed by the Ministry of Public Instruction with the advice of the Higher Council of Instruction. They are uniform for all France and each subject is outlined in a detailed syllabus. The greatest care has been taken to insure the continuity of subject matter and to emphasize its cross connections. The subject bands form an unbroken warp on which teachers and pupils work continuously for seven years weaving a clearly conceived pattern of learning and cultural experience. The classical program carries a wealth of inherited tradition, refined by the unbroken experience of six centuries. As a medium of culture in literary taste, in refinement and precision of expression and in generalized thinking, it is not surpassed and perhaps not equally by any similar discipline. The mathematical instruction, while fairly abstract, reflects the national genius for exact logical thinking to a high degree. The scien-

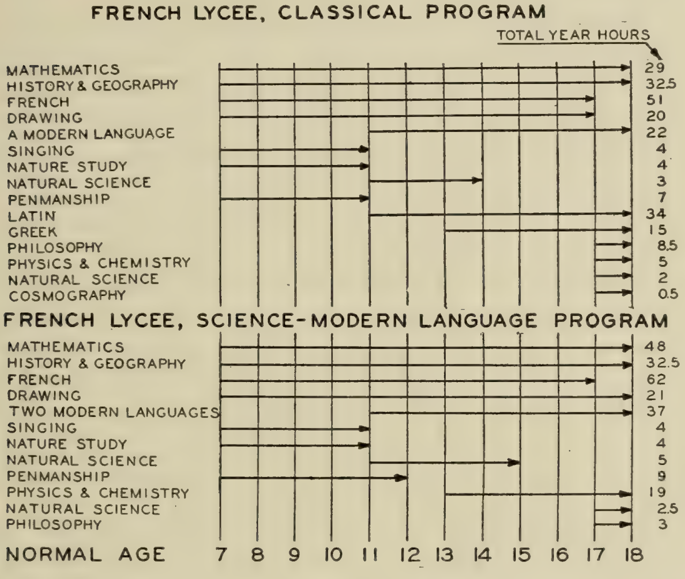

Fig. 2. Schematic Plan of Classical and Modern Curricula of French Lycée.

tific features are less mature in their development. The syllabus of physics and chemistry, while fairly extended in scope, bears the marks of an artificial synthesis rather than a normal evolution.

Regime of Secondary Schools.—The French secondary school is one of the most characteristic national institutions. The instruction is given chiefly through oral exposition of carefully selected materials, supplemented by voluminous written exercises and careful memorization by the student. The relations between professors and students are fairly formal. There is little of the give-and-take teaching of the German *gymnasium* or the easy-going *cameraderie* of many American high schools. The school is regarded as an agency of intellectual and moral culture rather than of social adjustment, all of the latter being left to the home and the family. Discipline is unremitting, but humane. Two points are ceaselessly emphasized, close application to specific tasks and facility of expression, both oral and written. The promotion examinations from year to year are of only moderate difficulty, but the comprehensive examinations of the baccalaureate are inexorable. French youth approach this ordeal with great seriousness, for on it hangs the possibility of entering the university, the most favored professional schools, the restricted professions and the higher civil posts.

Mathematical Preparation for Engineering Studies.—The specific mathematical preparation for the baccalaureate in the science options is shown schematically in Figure 3. The cumulative character of this training is self-evident. The treatment of the subject may be likened to a spiral, since there is considerable repetition from year to year but the ground is traversed with increasing reach and intensity. This principle of concentric teaching is carried up into the higher schools and resulting familiarity with the basic concepts, vocabulary and operations of mathematics is fairly startling to one accustomed only to the touch-and-go teaching of mathematics in detached units.

The baccalaureate admits without restriction to the general faculties of the universities. Most of the higher technical schools, however, require a still higher level of preparation in mathematics and science, set a strict limit to their admissions and select their students through a rigorous competitive examination known as a *concours.* Advanced preparation for the *concours* is given in special classes known as *mathématiques spéciales* which are held in certain *lycées* in the larger cities. A number of *lycées* in Paris which are devoted exclusively to this special program divide the classes into separate sections and a small group of highly selected professors takes each section in hand in intensive preparation for a particular *concours,* one for *Polytechnique,* one for *Centrale,* one for *Normale,* etc. The program in *mathématiques spéciales* consists nominally of one year of intensive work in higher algebra, analytical geometry, calculus, elementary differential equations, descriptive geometry, rational mechanics, physics and chemistry. Actually, nearly all students devote two years to the program, for while one is free to attempt the *concours* after a single year he rarely succeeds in this attempt and so returns to fortify himself for a second or even a third trial. In order to lessen the deadening effects of repetition the program has recently been revised into elementary and advanced stages, arranged on the "spiral" plan mentioned above.

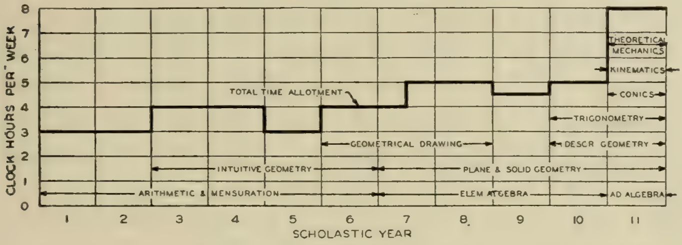

FIG. 3. Mathematical Preparation for the Baccalaureate.

The ground covered in *spéciales,* when added to that of the baccalaureate in mathematics, is virtually equivalent to the sum total of the mathematics, general physics, general chemistry, descriptive geometry and rational mechanics which make up the common base of American engineering curricula. There are differences of detail and of emphasis; the French give less time to detailed numerical examples and to laboratory manipulations, but the student usually gains a firmer grasp of the underlying concepts and logic of the subjects and displays markedly superior ability to follow a generalized treatment of the technical sciences.

Estimate of French Preparatory Education.—As a preparation for higher technical studies the French system has distinctive merits and defects which impress a foreign observer strongly. That it produces a high standard of literacy, a mastery of the mother tongue, a capacity for exact and generalized thinking, a well developed geometrical sense, and a facility in mathematical analysis is very evident. French students are clever at sketching and drafting, but not adepts in other manual arts. The training in experimental sciences leaves much to be desired and has drawn severe criticisms from French engineers. The higher engineering schools are unwilling to accept the secondary options on even terms and many of them grant a premium for the baccalaureate with Latin or philosophy. It is a striking fact that the major industrial interests of France have been virtually unanimous in their support of the classical basis of secondary education. One year of intensive work in *mathématiques spéciales* is generally regarded as an admirable discipline, but the custom of repetition has been severely criticized by French engineers and educators, by none perhaps more severely than by the distinguished mathematician Prof. P. Appell, recent Rector of the Sorbonne:

> ''The great criticism to be levelled against our instruction in France is that our system tends to fatigue our youth, to destroy its initiative, while on the contrary it ought to stimulate that initiative and introduce young people to life eager and fresh, full of curiosity and ardor.''

From an American point of view, the most general criticism of the entire scheme of secondary education in France is that it places an undue premium on receptivity and far too little on creative effort.

Primary and Vocational Education.—The primary schools of France provide a uniform program in common branches, morals, civics and physical training to the age of twelve, then ramify into various vocational branches. There are many admirable vocational schools (*écoles professionelles*) which may be entered at this stage, some under municipal and others under State auspices. Paris has fifteen such vocational schools and a special school for the training of their teachers. The trade courses for girls are usually two years in length, and those for boys three or four, according to the trade. There are also higher primary schools in the principal centers with a three-year course which begins at the age of 13 and which leads to the certificate of higher primary studies. These schools are fairly comparable to American technical, commercial and agricultural high schools. No Latin is taught, but mathematics, elementary science, modern languages, drawing and manual arts are emphasized. The students are ambitious and work hard, reaching a standard of achievement at 16 equal to that of graduation from an American high school. The technical work in drawing and shopwork is especially effective and occupies 41 out of a total of 100 year-hours in the three-year curriculum.

The best of the higher primary school are little inferior to the *lycées* in equipment and personnel and are tending to approach them in the higher parts of their program. One such school in Paris, *Ecole Turgot,* gives the complete preparation for the baccalaureate in the science-modern language section and has a special advanced section preparing for the *concours* of *Ecole Centrale*. The methods of teaching, however, are usually more intimate and freer than in the *lycées* and resemble the better practices of our own secondary schools. There are a number of *Ecoles Nationales Professionelles* which offer programs comparable to the higher primary schools, but with application to particular groups of industries such as textiles, metal working, etc. Both groups of schools offer preparation for the *concours* of admission to the six *Ecoles Nationales d'Arts et Métiers,* higher schools of mechanic arts which stand at the summit of the primary educational system and lead to the degree of *Ingénieur d'Arts et Métiers.*

B. Characteristics of the Higher Technical Schools

Types of Schools.—French engineering schools have a marked quality of individuality. There are more than forty of them and no two, apart from the six similar *Ecoles d'Arts et Métiers,* are as much alike as Rensselaer and Cornell. There are diverse levels of admission and of specialization which make classification difficult. Each school, however, prepares for a fairly definite type of career. Grouping them by this principle, we have:

1. Schools preparing primarily for the State services:

Ecole Polytechnique (A school of recruitment and of preliminary scientific formation)

- Schools of application
  - Military
  - Naval
  - Civilian

2. Schools preparing for general industry:

- Ecole Centrale des Arts et Manufactures
- Engineering schools at Lyons, Marseilles and Lille
- Six Ecoles Nationales d'Arts et Métiers

3. Schools preparing for specific industries and branches of engineering:

- Instituts techniques in the universities
- Private polytechnic schools
- Private monotechnic schools

4. The Conservatoire des Arts et Métiers at Paris, a public institution for part-time technical instruction.

Many other classifications might be made, but the most significant, perhaps, is the clear differentiation between schools which emphasize the intellectual side of engineering and those which emphasize its practical side. The so-called *grandes* *écoles* of Paris, the more prominent university *instituts* and the leading private schools belong in the former category, the *Ecoles d'Arts et Métiers* and certain private schools which have been modelled upon them in the latter. The former give great prominence to oral teaching and to projects of engineering design, a moderate emphasis to laboratory instruction, and little or no attention to manual training, while the latter group reverse this order completely. A few of the provincial and private schools have taken middle ground.

Common Characteristics.—Traditions and usages which have been growing up since the creation of the *Ecole des Ponts et Chaussés* in 1747 have marked all the technical schools of France with certain common characteristics. Prominent among them are: (1) definiteness of aim and function, since each school prepares for a fairly specific form of career; (2) strict limitation of the numbers admitted in each annual "promotion"; (3) selective admission, usually by competitive examinations; (4) insistence upon the intellectual homogeneity of student bodies, and the absence of all effort to adapt work to individual differences; (5) a closely integrated curriculum of prescribed studies; (6) a disciplinary regime of work, with insistence on a high degree of assiduity; (7) the universal use of the lecture as the primary mode of instruction; (8) the flair for generalized theory, with relatively small attention to numerical examples; (9) the large weight given to design projects of substantially real magnitude and character; (10) the large weight given to individual oral interrogations and the relatively small weight given to written tests; (11) the absence of a full-time faculty, technical and administrative branches being taught by engineers in active practice, and sciences and languages by professors from neighboring universities and *lycées;* (12) the absence of intimate contact between the major teachers and the students; (13) the absence of post-graduate students, except those pursuing complementary courses for purposes of specialization; (14) and the small volume of research in progress, in consequence of the divided interests of the professors.

Forms of Organization.—No French engineering school possesses a "faculty" in the corporate sense of the term. The professors usually teach a single course, involving two or three appointments per week, and spend little additional time at the school. There are usually a few full-time *chefs de travaux* who supervise the practical exercises and frequently a number of *interrogateurs* or oral examiners, mostly mature men of moderate abilities who resemble the permanent assistant professors in American schools. Continuity of administration is secured through a permanent director and secretary. Since there is no faculty to act on legislative questions, these functions are placed in the hands of an advisory council in which prominent government officials, industrial and civic leaders, engineers and savants are associated with the principal officers of the school. In some cases there are two councils, one a small administrative body and the other a large advisory body which passes upon the curriculum and major educational policies. This lay representation is a valuable asset. It gives contact with the world of affairs and, in many cases, brings financial and industrial support. There is often an interlocking of teaching staffs and of representation in school councils which aids in the coordination of neighboring institutions.

The University Institutes.—The traditional forms and ideals of French university life do not lend themselves readily to so highly integrated a discipline as the training of an engineer. The university is conceived to be a *foyer de la vie intellectuelle* and its purpose to foster curiosity of mind and to promote free inquiry and speculation by teacher and student alike. The principle of academic freedom is religiously observed. There is no articulated curriculum and the regime of work is not highly organized. The sciences are pursued disinterestedly and with little or no interconnection or professional orientation. The American scheme of departmental organization with laboratory facilities in common is unknown. The professorial chair is the unit of organization and each has its own adjuncts of teaching and research. The courses are relatively self-contained and each has its own complements of practical exercises. All university professors are public officials, named by the President of the Republic, irremovable, paid by the State, and practically free from all administrative discipline. No one can be appointed to the professorship who does not hold the State doctorate or *agrégation*. Once appointed a man is considered to be a *savant* by career.

It would be possible to create individual chairs of the technical sciences within this academic frame, but scarcely a professional school of engineering on the approved French pattern. The *institut technique* is an expedient created to solve this dilemma. It is in effect an autonomous and self-contained school, affiliated with a university faculty of sciences. The *institut* has its own staff, establishes its own requirements for admission, and regulates for itself its scale of fees, its budget and its system of instruction, independent of the university proper. The director, who is usually a permanent officer rather than an elective dean, is a titular professor of the university and serves as a connecting link with its administration. The teaching staff consists of professors from the faculty of sciences, engineers in practice in the city or region, and professors from neighboring *lycées*. There are usually a few full-time teachers of junior rank attached to the *institut* itself. The curriculum is passed upon by a *conseil de perfectionnement* which includes lay members representing industrial interests. In matters of plant and equipment each *institut* must fend for itself. The usual plan is to set up a congeries of monotechnic *instituts*. At Nancy, for example, where the technical instruction has had the largest development in any of the universities there are ten distinct *instituts*. Grenoble, on the other hand, has an *institut polytechnique*.

Practically the entire extension of engineering education outside of Paris since 1890 has taken this form. Ten of the seventeen universities maintain one or more *instituts* but most of them are still relatively young and small, and lack the prestige and resources of the older schools of Paris. They are more lenient, as a rule, in their admission requirements and some of them maintain preparatory sections to facilitate the entrance of non-bachelors from the higher primary schools. In the principal industrial centers, especially at Lille, Nancy, Grenoble, Lyons and Toulouse, the *instituts* have intimate relations with the regional groups of industries and have received substantial subventions from their hands.

Levels and Conditions of Admission.—French engineering schools may be arranged on five distinct levels according to their admission requirements (see Fig. 1, p. 824):

1. The certificate of higher primary studies,
2. The first part of the baccalaureate,
3. The complete baccalaureate in mathematics,
4. The course in *mathématiques spéciales,* usually two years,
5. Completion of *Ecole Polytechnique* or some other higher school.

The *Ecoles d'Arts et Métiers* are on the first level, certain private schools in Paris on the second, most of the university *instituts* on the third, *Ecole Polytechnique* and *Ecole Centrale* are representative of the fourth, and the schools of application and certain schools of higher specialization in Paris are on the fifth. A number of the schools maintain two or even three levels of entrance to successive years of the course, and some have preparatory as well as professional divisions.

Only a few of the less exacting provincial schools admit on certificate alone. Limitation of numbers is the universal rule and whenever the number of candidates exceeds the quota of places available the selection is made by a severe competitive examination or *concours.* This practice is not yet common among the university *instituts,* but many of them require an *examen de capacité* of fairly difficult character. It is a safe generalization that no other national group of technical schools is so exacting in its admission requirements or so insistent upon the intellectual homogeneity of its student bodies.

Limitation of Numbers.—The limiting of facilities and numbers appears to be a settled national policy. In view of a tendency to overcrowd all the white collar callings the authorities deem it expedient to limit the recruitment of engineers at the source. Much may be said in favor of this policy in a country where population is stationary, where public works are already largely developed and natural resources fully exploited, where industry is organized on a moderate scale and where there is little urge to penetration in foreign markets. The engineering profession as a whole supports this policy as the bulwark of its relatively superior economic status, but some observers, notably M. LeChatelier, have condemned it severely as a great handicap to France in industrial competition with Germany.

There was a reaction at the end of the late war and a movement toward expansion and relaxation of entrance requirements gained some headway. The ranks of engineers had been sadly thinned, industry was much in need of rehabilitation, the devastated areas were awaiting reconstruction and there was an abnormal demand for admission from young men whose education had been interrupted by military service. Among the measures proposed were the elimination of the class in *mathématiques spéciales* and its replacement by a preparatory year in the higher schools, the replacement of the *concours* by a simpler *examen de capacité,* and the making of eliminations at the end of the preparatory year. It was at one time proposed to establish *facultés techniques* in all the universities by legislative act. None of these plans prevailed. A number of the schools raised their admission quotas and took steps to renovate and enlarge their equipment. Once the emergency had been met a new level of numbers was stabilized about ten per cent above that of the prewar period.

Trustworthy statistics concerning the total output of engineers are not available. In his memorable paper before the *Société des Ingènieurs Civils* in 1917 M. Guillet, the eminent metallurgist and director of *Ecole Centrale* of Paris, estimated that the so-called *grandes écoles* furnished a quota of from 300 to 350 civilian engineers per year, the university *instituts* from 250 to 300, and the private schools of Paris about 200 additional. Allowing for duplications, the net total from these sources was probably between 700 and 800 per year. To this number an additional 100 to 150 might be added to cover provincial schools not included in M. Guillet's estimates. The six *Ecoles d'Arts et Métiers* and a few private schools of like character supplied about 600 men trained for the supervision of industrial production. The grand total of engineer graduates of these several categories at the pre-war level was probably between 1300 and 1500, and this total included technical chemists and geologists as well as engineers in the stricter sense of the term. Post-war expansion has probably increased this quota by ten to fifteen per cent. In round numbers, the annual production of engineers and industrial technicians of the higher ranks relative to total population may be estimated at 1 to 25,000 in France, as compared with 1 to 11,000 in Germany and 1 to 12,500 in the United States.

The Concours of Admission.—The competitive system of admission deserves special attention as it is peculiar to France and one of the most significant features in her national system. Two examples may serve to illustrate the most salient characteristics, the *concours* of *Ecole Polytechnique* representing the higher levels of admission and that of the *Ecoles d'Arts et Métiers* representing the lower levels. The ratio of the candidates examined to the number of places available is the commonly accepted index of the prestige of the school. The upper limits of the scale are fixed by *Ecole Polytechnique* and *Ecole Centrale,* which commonly have over 2000 candidates apiece for 225 and 250 places respectively.

While there are differences of detail from school to school, the plan of the *concours* is much the same. There are both written and oral examinations, in two stages, the first eliminatory and the second final. The *concours* not only solves the problem of selective admission but also disposes of the whole problem of student elimination and scholastic discipline in advance. French schools follow methods of mass teaching which make no allowances for individual differences and it is deemed essential that the student bodies shall be intellectually homogeneous, fully disciplined in work habits and able to follow oral instruction with great facility. The *concours* has been much criticized by French engineers and educators. The most valid charge, perhaps, is that it ignores many of the aptitudes which are essential to the engineer in favor of qualities which are more fitting to the savant than to the man of action. The present usage is so deeply rooted, however, that there is little prospect of a radical change.

Concours of Ecole Polytechnique.—No diploma is required, but it is usually assumed that the candidate has had two years of intensive preparation in the class of *mathématiques spéciales.* The candidates are therefore normally 20 years of age and have had a theoretical grounding in higher mathematics and science superior to that of a junior in an American engineering college. The first series of examinations, consisting of written and graphic tests, is given simultaneously in twenty-eight cities throughout France; the second series, which consists of individual oral examinations, is given by a special jury only in Paris. Each part is graded on a scale of 20 and the grade is multiplied by a weighting coefficient to determine the points obtained. Complete failure in any single part eliminates the candidate and a single grade below 4 places his name on a provisional list. The ''admissibility'' of the candidate is determined by the points gained in the written and graphic tests and in the first oral test in mathematics. Only those who are classed as admissible take the oral examinations of the second degree. The final ranking which fixes the selection of the promotion is the total of all the points obtained, with certain majorations as indicated below:

CONCOURS OF ECOLE POLYTECHNIQUE (1924)

Examination	Written or Graphic Part		Oral Part
	Hours	Weight	Weight
Mathematics (2 written, 2 oral parts)	8	14	50
Calculation	1	1	
Descriptive Geometry	4	3	
Physics	3	6	14
Chemistry	3	3	7
French Composition	4	10	
Foreign Language, translation	1½	3	5
Foreign Language, theme (optional)	1½	*	
Free-hand Drawing	3	4	
Mechanical Drawing	3	3	

SUMMARIES OF WEIGHTS

Written Examinations	37	Mathematics	65
Graphic Examinations	10	Physical Sciences	30
Oral Examinations	76	Languages	18*
Physical Aptitude	4	Graphics	10

MAJORATIONS

Baccalaureate in philosophy or with Latin	15 points
Military record, according to length and distinction	0 to 100

* A majoration is granted equal to double the number of points by which the grade in the optional examination exceeds 10.

The majorations for the baccalaureate in philosophy or with Latin are premiums for breadth of education, since the *concours* itself fixes the qualifying levels in science and mathematics. This premium reflects the fairly general conviction among educators that the older discipline of secondary education produces greater breadth, capacity for generalized thought, discrimination of judgment, and precision and grace of expression.

The examinations differ considerably from the types familiar in America. The written parts are appropriately called compositions; there are fewer questions, they are stated broadly, and the student is left free to choose the scope and form of his treatment. A typical three-hour examination in mathematics:

"Given: a being positive, o being the origin of axes, a point M in space experiences a force of intensity a^3/oM^2 directed from M toward o and a constant force of intensity a parallel to a fixed direction that may be taken as the positive direction of the axis ox.

1. Demonstrate that the resultant of these two forces is derived from a function of forces which you are to determine.

2. Indicate briefly the various forms of the sections (C) of equipotential surfaces by the plane xoy. A curve (C) is a portion of an algebraic curve of which only the useful part is to be traced. The determination of the sign of dy/dx and of the number of points of a curve (C) where the tangent is parallel to ox is postponed to part 4.

3. Each of the curves (C) admits of an asymptote $x = b$. Trace on the same diagram the curves corresponding to the asymptotes obtained for $b = -3/2a$, $b = 0$, $b = 3/2a$, $b = 2a$ and $b = 5/2a$.

4. Find and construct the locus of the points of curves (C) where the tangent is parallel to ox. Determine the value of b corresponding to the curve (C) for which this horizontal tangent is a tangent of inflexion.

5. Find the distance between the point where a curve (C) cuts the axis ox and its asymptote $x = b$, when b is greater in absolute value than $2a$. What is the limit of this distance when b becomes infinite? What conclusion can be drawn concerning the form which the curves (C) tend to assume when b is increased indefinitely?

6. Find and construct the lines of force of the field considered."

A typical composition in chemistry:

"1. What is understood by catalysis? Give examples of catalytic reactions. Application of catalysis to the production of sulphuric anhydride.

2. Bromine and hydrobromic acid."

Typical topics in physics:

"1. Draw with care the system of isotherms of a true fluid in coordinates, taking the pressure p as abscissae and as ordinates the product pv of the pressure of the volume, and tell what you can of this system. Under what conditions may such a fluid be treated as a perfect gas? How can these conditions be represented on the preceding system of isotherms? What can be said on this subject relative to the determination of the molecular weights of true gases?

2. The measurement of the velocity of light.''

A typical group of questions put by an oral examiner:

''1. Tangential and normal components of acceleration.

2. Imaginary roots of an equation with real coefficients.

3. Curves such that the projection of the radius vector on the tangent is constant. Geometrical solution.''

Concours of the Ecoles d'Arts et Métiers.—This competition is commonly taken at the age of 16 on completion of the industrial section of the higher primary school. There are two stages: the first is a series of elimination examinations which may be taken at the chief city of each Department and in other designated centers; the second is the *concours* proper, which is held only at the *Ecoles d'Arts et Metiérs* themselves. The elimination test includes seven items, each of which has equal weight: (1) a dictation in French, followed by questions concerning its language and meaning; (2) a composition in French; (3) a test of lettering and free-hand drawing; (4) a test of machine drawing; (5) a written test of algebra; (6) a written test of geometry and of elements of descriptive geometry; and (7) a test of physics and chemistry. An average grade of 10 on a scale of 20 is required for eligibility to the *concours* proper, which includes written, manual and oral examinations with the following weights:

CONCOURS OF ECOLES D'ARTS ET MÉTIERS (1924)

Examination	Weights Written	Oral
French Language	3	3
Algebra and Trigonometry	2	4
Geometry and Descriptive Geometry	2	4
Physics and Chemistry	2	4
Machine Drawing	4	
History and Geography		2
Foreign Language (Optional)	*	*
Manual Arts (performance)		5

* A majoration is allowed equal to double the excess of the grade above 12.

The following typical questions suggest the order of difficulty of the examinations:

> "A truck weighing three tons is driven at a speed of 18 kilometers per hour on a straight and level road. The truck is brought to a stop by passive friction, assumed to be constant, one minute after the suppression of the driving force. Find:
>
> *a*. The distance traversed after stopping the motor;
> *b*. The value of the passive resistance;
> *c*. The value of the propulsive force;
> *d*. What supplementary braking force must be applied to stop the truck in 30 seconds;
> *e*. What quantity of heat would then be developed in the brake?"
>
> "There is given an isosceles triangle ABC (AB = AC); a circle of variable radius is tangent to BC at B. The line AB extended cuts this circle at M and a line from M to C cuts the circle at P. Find the geometrical locus of the point P as the radius of the circle is varied."
>
> "How is the French domain of North Africa constituted? What is its economic and political importance?"

Forms of Teaching.—The teaching in French technical schools may be described under seven characteristic forms:

(1) The *cours,* which is the central feature in all but the ultra-practical schools, is a series of professorial lectures given to an entire promotion in a large ampitheatre. There are usually two or three sessions per week, each occupying from an hour and a quarter to an hour and a half. The treatment of the subject is encyclopaedic and topics follow each other in rapid succession. The theoretical development is given once in passing, but is not hammered home by constant repetition and drill. The mathematical analysis is usually general rather than concrete, with a free use of partial derivatives and differential equations. Experimental demonstrations in the sciences are used more sparingly than in American and German schools. In the technical courses the current state of the art is treated *in extenso,* with a generous use of wall charts and projections. After a brief historical review the principal types, processes or constructions are taken up in

rapid succession, their advantages, limitations and characteristics are stated briefly but well, and the lecturer passes on to a summary analysis of the technical features of design and construction. This analysis covers general cases, with only secondary emphasis on numerical applications. The students take voluminous notes, except where the lectures have been published in an abridged form. There is no class discussion and questions are seldom raised by the students. Informal conferences with the professors are uncommon. One eminent professor observed that when he was approached with a question after a lecture, it was invariably by a foreigner. The system is formal in the extreme, but the students are prepared for it by the discipline of the *lycée* and the lecturer often redeems the situation by his clear and polished exposition.

(2) The *répétition* is a less formal exercise than the lecture and is usually conducted by a tutor. Attendance is often optional. Matters which have been previously treated in lectures are taken up for review, explanation and amplification. No new matter is introduced, but the student is given opportunity to raise questions on points which he has not clearly understood.

(3) The *conférence* is less formal than the *cours* and more closely resembles the seminar. The topics treated are often less connected in their sequence. Many of the schools give a large weight to *conférences* conducted by active practitioners other than the professors. In some cases there are no collateral exercises or projects, no examination is given and little weight is assigned in the general ranking of the students. In other cases, as in the teaching of foreign languages, the *conférence* is a veritable recitation section and is graded carefully.

(4) The *interrogation* is an individual oral examination. At *Ecole Centrale,* for example, where each student is given a twenty-minute private oral quiz in one subject each week, a special staff of examiners is set aside for this service, and there are numerous cell-like examination rooms, each fitted

with two chairs and a small blackboard. This method of examination is peculiar to the French schools and is considered very effective in keeping check on the progress of students under the usual mass systems of teaching.

(5) The *travaux pratiques* consist of laboratory, drafting and field exercises, performed in small squads under the supervision of *chefs de travaux.* They are usually adjuncts of particular *cours* rather than separate units of work. The methods of assignment, supervision, performance and report-making resemble closely the similar exercises in American schools, but an appreciably smaller proportion of time is usually allotted to this type of instruction. The reports are quite detailed and the drawings executed with much skill. Order and form of presentation are emphasized equally with the content.

(6) The *projet* is a full-scale engineering problem, including questions of selection, design and cost, which is assigned for individual work with little or no formal supervision by the teacher. The latter is an absentee, except during his lecture periods, and much occupied with active duties. He may spend one or two afternoons per month in the *salles d'études,* to afford students an opportunity for consultation, but for the most part the students are thrown on their own resources. Work of this character occupies the greater part of the student's time, apart from the *cours,* in the final year of the schools of application and at *Ecole Centrale.*

(7) The *stage* is a period of assigned duty and observation, in a plant, factory, mine, yard or field project. Most of the schools require *stages,* some in term time but more often in vacations. The term stages are usually of from one to three days' duration at a time. The State schools of application assign their *élèves-ingénieurs* to active field duty in the summers and augment in this manner the rather limited quota of practical exercises provided for in the curriculum.

Naturally, the division of time between these forms of instruction differs from school to school. Detailed comparisons are difficult to make as the published curricula and syllabuses seldom include a time schedule. M. Guillet included some comparative data in his notable paper of 1917 which, while out of date, are still of qualitative value. *Ecole Centrale* has since greatly extended its laboratories and has increased the proportion of practical exercises appreciably:

RELATIVE TIME ALLOTMENTS

Institution	Lectures	Projects	Exercises	Diverse
Ecole Centrale	52.0%	35.7%	12.3%	
Ecole des Mines	43.6	22.7	22.7	11.0
Ec. des Ponts et Chaussées	48.5	44.3	4.1	3.1
German Hochschulen	29 to 41%	71 to 59%		

Fees and Costs.—The tuition fees charged for regular university work in France are very low and seldom exceed a total of $20.00 per year. The fees of the technical schools and institutes are much higher as a rule, although the *Ecoles d'Arts et Métiers* make no charge for tuition and provide *pension* at a very low cost. The financial autonomy of the majority of the schools makes it necessary for them to cover practically the full costs of instruction by the fees charged. The prevailing forms of mass instruction, the nominal salaries paid to professors for part-time services, and the relatively small time given in many schools to *travaux pratiques* tend to keep the costs low. As one director proudly put it, "We pay in honor." Institutions like *Ecole Centrale* and the *Ecole Supérieure d'Electricité,* which charge a fee of $120.00 per year, are virtually self-supporting except for overhead and plant charges. The private *Ecole Spéciale des Travaux Publics* earns a modest profit on tuition fees ranging from $80.00 to $136.00 per year. The fees charged by the university *instituts* are somewhat lower; at Nancy, for example, they range from $50.00 to $60.00 per year. Many of the schools have special scholarship funds and there is a national office from which worthy but needy students may obtain "loans of honor."

Diplomas and Titles.—The title of *Ingénieur* carries a considerable prestige in France, but there appears to be no effort to restrict it to a homogeneous grade of attainment like the German *diplom-ingenieur* and the British Bachelor of Science. The diploma of *Ingénieur* is awarded on the authorization of the Ministry of Public Instruction and each school gives it a distinctive wording and abbreviation which indicate its source and character. *Ecole Centrale,* for example, gives the degree of *Ingénieur des Arts et Manufactures,* with the abbreviation *I. E. C.* (*Ingénieur Diplomé de l'Ecole Centrale*). There is a tendency in France to award the diploma of *ingénieur* for every sort of higher program in the technical sciences. All the institutes of chemistry award the diploma of *Ingénieur-chimiste,* although many of the programs include little or no engineering matter apart from industrial chemistry. Similarly one finds such diplomas as *Ingénieur-opticien* in technical optics, *Ingénieur-agronome* in technical agriculture, *Géologue-ingénieur* in applied geology, and many others.

The most recent addition to the list of higher degrees awarded by the universities is that of *Ingénieur-docteur,* which was instituted by the Ministry in 1923. This degree is not conferred by the technical schools themselves, but by the university faculties of sciences, since research is regarded as a university function rather than that of a professional school. Access to the doctorate is restricted to the graduates of a group of schools accredited by the Ministry on the advice of a representative council. It is interesting to note that graduates of the *Ecoles d'Arts et Métiers,* who receive only a restricted scientific training, are admitted on a par with those from the *grandes écoles.* The requirements for the doctorate consist of a sojourn of four semesters in a university laboratory and the defense of an original thesis before a jury of three members of the faculty of sciences. As yet there is little to indicate that this plan will supply the much needed stimulus to engineering research in French higher institutions, since few of the universities have effective staffs and facilities outside the realm of the pure sciences, except in the field of industrial chemistry. It will, however, open the way for engineers to qualify for State appointments as professors and may aid in time in the larger development of technical education in the universities proper.

Physical Facilities.—The special points of excellence in French technical education are mostly on the intellectual rather than the material side. Few of the schools are housed or equipped on a scale which would be acceptable to even the more modest American institutions and there is nothing which can be compared with the monumental installations to be found in Germany, Sweden, Switzerland and Holland. Most of the Paris schools occupy old buildings converted from other uses, making it very difficult to modernize and extend their laboratory facilities. *Ecole Centrale* has met this problem by the novel expedient of building a great subterranean laboratory under a central court. The *Ecole Spéciale des Travaux Publics,* a private enterprise, has a dual installation, the lecture ampitheatres being close to the Sorbonne in Paris and the extensive laboratory, shop, field and dormitory plant in the suburb of Arceuil-Cachan. The *Ecole Supérieure d'-Electricité* has just completed an admirable new plant on the edge of Paris with funds subscribed to a stock company by its patrons and the industries.

The provincial schools for the most part are equipped on a most modest scale. The *Ecole Centrale Lyonnaise,* an important institution in a great industrial center, has less to do with than many a small country college in America. The institutes of the University of Nancy have adequate and convenient laboratories, the cost of which was largely borne by the industries of the Lorraine region. The war interrupted an ambitious building program at Grenoble, which now stands two-thirds completed. The *Ecoles d'Arts et Métiers,* if Paris and Lille may be taken as representative have facilities for teaching the mechanic arts which are probably unsurpassed in the world, together with effective laboratories for the technical sciences.

The drawback is primarily financial, but not wholly so. The preeminence given to oral teaching, which runs through all of French education, and the part-time service of the professors have tended to reduce laboratory teaching to a secondary plane.

C. REPRESENTATIVE HIGHER TECHNICAL SCHOOLS

Prefatory Note.—The *technische hochschulen* of Germany are all variants of one common norm; once this has been described, distinctive details are easily fitted into the picture. No so with France, where the schools have such marked individuality that many samples must be chosen and the salient features of each traced out in order to create a composite picture. The thumb-nail sketches which follow are not detailed pictures. One line is emphasized here, another there, in an effort to suggest the complex whole in which each is a significant part.

Schools Preparing for State Services

Selection of Personnel.—Behind the shifting political front of French ministerial government stands an administrative structure of unusual stability, in which engineers have had a conspicuous place for several centuries. These careers are highly esteemed and competition for entrance is particularly intense. The State takes advantage of this situation to select and train for its technical services an elite of intelligence and scientific culture, and in the process to create an auxiliary reserve of officers for the technical arms of defense. The process of selection is progressive. The first step, and the most difficult, is to gain admission to *Ecole Polytechnique*. Only a limited number of subalterns in the bureaus of public works are advanced to higher posts and there are great advantages of prestige and association in making one's debut as a *polytechnicien*. Probably no other group in France is united by such bonds of solidarity as the graduates of this famous school. What this may mean to one's career may be judged from the fact that the heads of all the railroads of

France and of most of the mining and metallurgical industries, the chiefs of the several bureaus of public works, and the most prominent marshals of France, Foch, Joffre and Fayolle among them, are old *polytechniciens.*

The second step in this selective process is the competition for ranking at *Ecole Polytechnique.* Graduates have their choice among the several schools of application for the technical, civilian, military and naval services, within strict quota limits, in the order of their final ranking. The civilian services have come to be much preferred in recent years and it is now traditional that the first choices go chiefly to the *Ecole des Mines* and the second choices to the *Ecole des Ponts et Chaussées.* The competition for ranking in the schools of application, while less keen than at the *Polytechnique,* carries selection a further step toward the post of duty to which the graduate will finally be assigned. Tuition is free at *Polytechnique* and the cost of *pension* is nominal. The *élève-ingénieur* in the school of application receives a salary from the State which is sufficient to support him. The exceptional education thus obtained at a nominal cost, with the virtual assurance of a preferred career, gives the system an immense attraction. In return, the *élève-ingénieur* obligates himself to serve the State at least ten years before resigning to enter any private career.

Ecole Polytechnique.—The origin and function of *Polytechnique* have already been described, as has the *concours* of admission. The school appends to the Ministry of War and is conducted as a military establishment. The students are all internes and wear a distinctive uniform, the discipline is strict but not punctilious, considerable time is given to military branches, but there is little routine drill. No technical subjects are taught, as the exclusive aim may be described as a ''high scientific and intellectual formation.'' The professors, fifteen in number, command a high distinction. There are also forty-five tutors, interrogators, and laboratory instructors. The student body numbers 450, in two ''promotions.'' The curriculum, which covers four semesters, includes the following subjects and total time assignments:

CURRICULUM, ECOLE POLYTECHNIQUE, 1925

Mathematical Analysis (Advanced calculus and differential equations; theory of functions), 68 lessons of 1¼ hours.
Mechanics (Theoretical and applied), 73 lessons of 1¼ hours.
Higher Geometry (Pure and applied), 37 lessons of 1¼ hours.
Physics, 68 lessons of 1¼ hours, 12 manipulations of 2 hours.
Chemistry, 60 lessons of 1¼ hours, 16 manipulations of 2 hours.
Astronomy and Geodesy, 18 lessons of 1¼ hours and some exercises.
History and Literature, 60 lessons of 1¼ hours.
Political and Social Economy, 20 conferences of 1¼ hours.
German or English, 40 conferences of 1 hour.
Architecture, 12 lessons of 1¼ hours.
Free-hand Drawing, 60 sessions of 1½ hours.
Military Science, 26 conferences and some inspection trips.
Military and Gymnastic Exercises, 2¾ hours per week.

The system of ranking is unique. Grades are determined by weekly interrogations, occasional written tests, final examinations and the inspection of drawings and reports. Points are computed by multiplying the grade of each item on a scale of 20 by a weighting coefficient and by the number of the semester in which it is given, so that the work of the final semester counts four times as heavily as that of the first. Interrogations and final examinations have about sixty-eight per cent of the total influence, written tests twelve per cent, drawings five per cent, laboratory exercises four per cent, and miscellaneous items eleven per cent.

When one considers that this relatively abstract discipline —60 per cent pure and applied mathematics and 30 per cent physical science, with only 56 hours of laboratory instruction —is superposed on a preparation equal to the total theoretical equipment in mathematics and science of the American engineering graduate, *Ecole Polytechnique* looms up as the highest remaining citadel of formal discipline. The brilliant achievements of its professors and students constitute its chief defense. There is no doubting the intellectual valor of the French engineer, yet one can but question whether this static discipline is a fitting preparation for men of action rather than savants. Is it really serviceable to field officers of artillery and the tank corps, to supervisors of the State manufactures, to provincial superintendents of roads, canals and bridges? One of the most trenchant critics of French technical education, M. LeChatelier, himself a distinguished *polytechnicien,* scientist, engineer and professor, points out that the students of the original promotion in 1794 spent three hours a day in the laboratory of chemistry where the present students spend scarcely three hours per fortnight. He complains of the small place given to experimental science and to individual exercises:

> "There is too much of a tendency to consider the manipulations as mere annexes to oral lectures, destined solely to illustrate the latter."
>
> "A very grave fault in our scientific instruction, more especially to be charged against *Ecole Polytechnique* and the classes which prepare for it, is the insufficiency or even the absence of individual effort. The students are required to learn only by heart, an unproductive exercise. Engineers and officers are not called upon to pass their entire lives at examinations, as it is said the Chinese mandarins did. They will have to act for themselves and the study of the sciences is of interest to them only to the extent that it equips them better to direct their own activity."

The Schools of Application.—As already stated *Polytechnique* does not prepare directly for the State services, but for a group of special schools of application. Graduates entering the military services are given special training for the artillery, engineering, tank, aeronautic, ordnance and infantry corps; those entering the navy are trained for the engineering, commissary and hydrographic corps or as line officers; and civilian functionaries are trained in special schools attached to the bureaus of mines, bridges and highways, state manufactures, posts and telegraphs, and forestry. Two examples of special interest to this study, the *Ecole des Ponts et Chaussées* and the *Ecole des Mines,* will be considered in some detail.

The Ecole des Ponts et Chaussées.—This school appends to the Ministry of Public Works and is primarily a school of application for the *Corps* whose name it bears. Each year a group of thirty *élèves-ingénieurs* is received from *Ecole Polytechnique* for two years of training. A small number of junior engineers are also admitted from the ranks of the *Corps,* having been chosen by *concours* after not less than six years of service. The majority of the students, however, are *élèves titulaires* preparing for the practice of civil engineering in private capacities. This group is admitted by *concours,* based on the program in *mathématiques spéciales,* and follows a curriculum of three years, the first of which is a much abridged substitute for the preparation given at *Polytechnique.* In addition, there are usually several *auditeurs libres* or special students not candidates for the diploma. The two latter groups pay a moderate fee for tuition. The program of lectures, repetitions, and conferences, and the total number of class exercises given to each subject, is shown below:

CURRICULUM OF ECOLE DES PONTS ET CHAUSSÉES, 1925

Year I		Year II *		Year III	
Mathematical Analysis.	40	Strength of Materials..	36	Materials of Construction	12
Applied Geometry	28	Hydraulics	20	Reinforced Concrete ..	13
Mechanics	48	Construction Methods .	22	Metallic Bridges	16
Physics	35	Architecture	15	Masonry Bridges	18
Chemistry	35	Roads and Pavements..	20	Marine Construction ..	31
Architecture	30	Surveying	8	Rivers and Canals ...	31
Social and Political Economics	20	Railroads	30	Heat Engines	29
English	20	Mineralogy and Geology	20	Hydraulic Construction.	30
German	20	Industrial Electricity ..	32	Political and Financial Economy	35
		Administrative Law ...	33	Administrative Law ..	25
		English	20	English	20
		German	20	German	20

* Graduates of Ecole Polytechnique enter the 2d year.

In addition to the class exercises listed above eight practical exercises in applied geometry and seven in physics, together with three architectural projects are required in the first year; two laboratory exercises in strength of materials, five in mineralogy and geology, and six in industrial electricity are required in the second year, together with three projects in architecture, and one project each in hydraulics, roads and pavements and industrial electricity, and a few exercises in surveying; and one major project is required in the third year in each of the principal civil engineering branches. A *stage* of two months in a construction yard, shop, or field project is required at the end of each year. The school has no effective laboratories of its own, but makes use of the State laboratory for testing materials and the laboratories of the *Ecole des Mines*. There is an admirable collection of structural models, but it appears to be little used.

From the encyclopaedic character of the above program it will be evident that the pace of instruction is very rapid. The day-to-day home work in the two upper years is practically nil. In the last year practically all of the student's work is in the form of major projects, one of which is given out each month. An American *auditeur,* a Harvard graduate in civil engineering, describes the working of the system in the third year class, which may be taken as typical of much of the advanced teaching throughout France:

> ''The problem covers only one course, only one subject, but it covers it in a most complete and practical manner. For example, the project in reinforced concrete might be about as follows: The student is given data concerning a river over which there is an old unsafe bridge. He is told about the river stages, the foundations, the old piers, the building code to be followed, the current price of concrete, rods and excavation, and told to present the plan with details, together with a price estimate, for a reinforced concrete arch structure, using the old piers if possible, adding new ones if advisable. No more. The situation is put as nearly as possible in the way it would be encountered in practice. The student may get his data where he can, but by the time he finishes he has a very good idea of the subject in question. It is unfortunate that all such projects can not be arranged to come at the end of the course, to serve as a sort of review, but since all the courses end about the same time, obviously some must be distributed as the subject is just beginning to get under way.
>
> ''The projects all present a point of excellence in that the economic side of the question is stressed to the same extent as the technical one. The student is forced to consider that he is submitting a theoretical proposal, not for any structure which will stand up, but for a particular structure which he estimates could be erected at a particular price, and that the latter point will be counted just as heavily as the former when the final grade for the project is turned in. This is a feature which

appears but rarely in the problems presented to the American student at home. He is led to understand in a vague sort of way, as has been often quoted, 'The engineer is a man who can do for one dollar what any darn fool can do for two,' but while he is in school he has no chance to show to which class he belongs.

''It may be claimed that the French method asks too much of the student, that it calls for mature experience which he cannot possibly have at this stage of his career, that it calls upon him to solve questions that present themselves only to men in positions of comparatively high responsibility. All this is quite true, but the student on leaving school is to step into just that position of responsibility to which the American looks forward as a goal to be reached after a certain number of years of preliminary work. The attitude of professors and engineers toward men still in training is one which says, 'When you graduate, you will be somebody, you will know something, you will step into your place and fill it,' while on the west side of the Atlantic the attitude is very different; it says, 'When you graduate, you will be just a boy out of school with a lot of book notions, you will be of no particular value until experience has brought its practical training to add to your theoretical one.' That is why the French student is given problems which are more complete, more practical, and even too hard for him. He expects it. He thrives on it.

''The student also learns in his preparation for examinations. So he does everywhere; cramming is bound to be prevalent wherever there are tests at varied intervals. It is in the intervals and the nature of the tests that the differences of customs are to be found. The American student is brought up short at mid-years, at finals, and often in between, with written exercises. At *Ponts et Chaussées* the only check comes once a year, in the early summer in the form of oral examinations which last about half an hour per person. They do not follow from day to day, but there is always about a week of respite after each course is taken up to allow time to prepare for the next. This makes the period rather long, about two months in all. The oral test has a distinct advantage in that the professor has a better opportunity to assure himself as to what the candidate really knows, but the process is a long one and is hard on the man who could think things out if he had time, but whose mind works slowly. Obviously the best method would be to combine the two systems.''

Each item in the curriculum at *Ponts et Chaussées* has its own definite weight in the final ranking of the student. Examinations receive about sixty-four per cent of the total weight, projects thirty per cent, and the records of the vacation *stages* six per cent.

The Ecole des Mines.—This school is one of the most thoroughly organized and effective in France. Its purpose is to prepare young engineers for the State *Corps des Mines* and for the technical and administrative direction of mining, metallurgical and chemical industries. It is admirably installed in the Hotel Vendome, a remodelled mansion overlooking the Luxembourg gardens, to which extensive laboratory annexes have been added. It offers a single unspecialized curriculum, with which are combined field expeditions and *stages* of instruction in practical workings to make up an all year program as follows:

Lectures and practical exercises	29	weeks
Examinations	7	"
Geological expeditions	2	"
Practical stages	12	"
Vacations	2	"

The recruitment of the school follows the same plan as that of *Ponts et Chaussées*. The curriculum is three years in length, but the graduates of Polytechnique follow an abridged program of two years. The program of lectures and conferences is given below. The schedule of practical exercises is complex and does not admit of a simple tabulation. Lectures normally last an hour and a half and conferences one hour. Sixty per cent of the total time is given to practical exercises and projects, an unusually high proportion for French schools of this class. No attempt is made to reproduce in the laboratories the actual operations of the mineral and metallurgical industries, which are the special objectives of the practical *stages*.

CURRICULUM OF ECOLE DES MINES, 1925

Year I		Year II		Year III	
Mathematical Analysis	32	Topography	10	Industrial Chemistry	24
Mechanics	30	Mineralogy	35	Metallurgy	25
Physics	40	Paleontology	28	Applied Geology	38
General Chemistry	30	General Geology	40	Petrography	8
Exploitation of Mines	60	Analytical Chemistry	30	Heat Engines	20
General Metallurgy	27	Heat Engines	32	Construction Processes	13
Ferrous Metallurgy	28	Electricity	36	Railways	42
Modern Language	56	Mechanics of Materials	25	Mine Legislation	35
		Industrial Hygiene	10	Industrial Economics	24
		Modern Language	56	Modern Language	56

Practical Exercises

Drawing
Physics
General Chemistry
General Metallurgy

General Metallurgy
Electricity
Analytical Chemistry
Topography
Engineering Projects

Analytical Chemistry
Electricity
Mechanics
Industrial Chemistry
Engineering Projects

The roster of the nineteen professors affords a representative exhibit of the important collateral connections held by the teaching staffs of the engineering schools of the first rank. Three are members of the Academy of Sciences; four are consulting engineers for important mining and metallurgical companies; four are high executive officers of such companies; three have important research connections with industry; and one was formerly general manager of the State railways. French opinion is unanimous on this point, that only those who ''have a foot in the industry'' are qualified to teach the distinctly engineering branches.

Schools Preparing for General Industry

Ecole Centrale des Arts et Manufactures.—A distinctive feature in France is an unspecialized type of training for the general direction of industries. *Ecole Centrale* was a pioneer in this field and is still its foremost exemplar. It is one of the largest technical schools of France, with 750 students enrolled. The selection by *concours* is so stiff that there are practically no eliminations in course. The students follow a common program of lectures and interrogations, but some degree of specialization is provided for in the practical exercises and project of the third year, with an option between mechanical construction, chemistry, and mining and metallurgy. The subjects covered by the common program constitute an encyclopaedic treatment of industrial technology:

PROGRAM OF COURSES, ECOLE CENTRALE, 1925

Year I	Year II	Year III
Mathematical Analysis	Mechanics of Materials	Applied Mineral Chemistry
General Mechanics	Geology and Mineralogy	Applied Organic Chemistry
Kinematics	Mineral Chemistry and Analysis	Hydraulics
Descriptive Geometry	General Metallurgy	Exploitation of Mines
General Physics	Civil Constructions	Ferrous Metallurgy
Industrial Physics	Framed and Concrete Structures	Railroad Way and Operation
Organic Chemistry and Analysis	Electrotechnics	Industrial Legislation and Economics
Thermodynamics and Fluid Mechanics	Heat Engines	Industrial Hygiene
Machine Design	Gas Fuels	
Architecture	Railroad Equipment and Motive Power	
Civil Constructions		

Ecole Centrale is one of the few higher schools of Paris which has a plant originally designed for its purposes. The growth of its laboratories illustrates the backwardness of this side of French technical education and the difficulties met in efforts to raise it to an effective level. The plan of the building is a hollow rectangle covering a city block in a congested area, with no space available for extensions. When the build- was erected in 1882 extensive laboratories of chemistry were installed, but the first engineering laboratories were not introduced until 1902. The school is financially autonomous and the fees leave but little margin above the operating costs. Money for equipment must therefore be raised from outside sources and a *Société des Amis de l'Ecole Centrale* was organized to secure funds from individuals and industries, to purchase laboratory equipment and to hold the title to the same. Through its efforts laboratories of electrical measurements and electrical machinery were provided in 1902 and ten years later laboratories of heat engines, hydraulics and hydraulic motors. The first two were installed in cavern-like basement rooms ill adapted to laboratory uses and ground floor rooms were sacrificed from other uses for the latter group in 1912. In 1913, through the initiative of the newly appointed professor of metallurgy, M. Guillet, laboratories of industrial physics and physical metallurgy were added, followed soon after by a laboratory of chemical technology. The war interrupted this process of growth, but an ambitious program of laboratory extensions was organized immediately after its conclusion. The *Société des Amis* raised a fund of 8,000,000 francs by subscription, chiefly from industrial concerns, and secured many donations of equipment. Space for extensions was gained by creating a vast subterranean laboratory under the central court, with a floor space of 2,000 square meters. This was arranged in three bays, one for electrical machinery, one for machine tools and foundry equipment, and one left vacant for future installations. Laboratories for testing materials and for heat treatment were also added on the ground floor.

The laboratory of electrical machinery has sixteen identical platforms, each with a complete ensemble of eight machines and a switchboard. With this exception there is practically no duplication of equipment. The laboratory of heat power, for example, has one boiler, one steam engine, one gas engine and one Diesel, all of considerable size. The laboratory of materials has a 30-ton tension machine, 20-ton compression machine, and an ensemble of smaller apparatus for tests of impact, hardness and fatigue and for the routine testing of cement. The conditions are rather better than typical of French engineering laboratories in general. There is an excellent collection of machine tools and molding machines, most of which are used for demonstration purposes only. There is a small shop for repairs and for student instruction.

A large place is given to engineering projects, executed in the *salles d'études* or numerous small rooms in which each student has a private desk and locker. The regimen and discipline are strict. The morning hours are given to lectures, the afternoons to practical exercises and the evening to preparation. Each student undergoes a private interrogation of from twenty to thirty minutes' duration each week, taking his several courses in rotation. *Ecole Centrale* is rated as one of the most arduous schools of France and its students show the effects of hard work and close confinement. There is little provision for recreation. A cafeteria is maintained at the school and there is a near-by residence hall for students from a distance. The alumni are planning to erect an extensive residence hall as one unit of the new *cité universitaire*, a living center for students of all the higher schools of Paris.

Ecole Centrale Lyonnaise.—This school was the first higher school of industrial technology created outside of Paris. It is a local and independent institution, operated under the patronage of the Chamber of Commerce of Lyon. It is a neighbor of the University of Lyon and draws heavily on the faculty of science for its teaching staff, but there is no organic connection between the two. There are three promotions of 100 students each and a small class, usually less than ten, of post-graduate students of electrical engineering. Undergraduates follow a common program. No diploma is required for admission but the normal level corresponds to that of the baccalaureate in mathematics. Bachelors have only to take a simple examination in drawing, but non-bachelors must satisfy an *examen de capacité* in mathematics, physics and chemistry, French, machine drawing and architectural drawing, parts of which are written (15 hours) and other parts oral.

CURRICULUM AND EXERCISES, ECOLE CENTRALE LYONNAISE, 1925

Year I		Year II		Year III	
Algebra	124	Calculus	124	Machine Design	62
Analytic Geometry	62	Analytic Mechanics	62	Hydraulics	42
Descriptive Geometry	32	Applied Mechanics	62	Graphic Statics and Mech's of Mat's	46
Analytic Mechanics	32	Geology	31	Heat Power	62
Physics	93	Industrial Physics	62	Structures	32
Chemistry	93	Chemistry of Metals	62	Public Works	42
Mineralogy	32	Electricity	31	Railways	22
Surveying	36	Elements of Technology	15	Electrotechnics	46
Elements of Technology	15	Metallurgy	26	Elec. Measurements	16
				Chemical Analysis	31
				First Aid	10
				Industrial Law and Organization	20

Practical Exercises

Physics	Geology	Chemical Analysis
Chemistry	Chemistry	Heat Engines
Mineralogy	Electricity	Electrical Measures
Drawing	Metallurgy	Machine Tool Work
Wood Work	Machine Drawing	Inspection Trips
Surveying	Forge and Bench Work	Projects
	Projects	

The corps of professors is made up as follows: Seven from the faculty of sciences of the University; three from *Lycées* in Lyon; twenty from practice; and five primarily connected with the school. In addition there are thirteen teachers of junior rank, mostly full-time. The laboratory and shop facilities are modest and hard worked. The machines are small and but one of a type. The installation is simple and flexible. Each class is taught as a unit in design courses; laboratory groups number twenty-five, shop groups twelve, and surveying groups ten men each. The scientific laboratories are very simply fitted and only fairly adequate. There are weekly oral examinations and written finals. The atmosphere of the school is one of hard and devoted work, by students and teachers alike. One can but wish that the school had equipment equal to many a prairie college in America.

Schools Preparing for Specific Branches of Engineering

There are two types of schools to be exemplified, one giving only intensive complementary instruction and the other a complete engineering curriculum. The former type of program, which seems to be peculiar to France, usually occupies a single year; the latter type is ordinarily three years in length.

The Ecole Supérieure d'Electricité.—This is the most notable of the schools of intensive specialization and has the added distinction of being the only engineering school maintained by a professional society of engineers. It is organized as a non-profit corporation and its equipment, newly installed at a cost of 12,000,000 francs, has been provided entirely by subscription made by the electrical industries and a few individual patrons. The school is administered by a commission in which are represented the *Société Francaise des Electriciens,* the subscribing industries, the University of Paris, *Ecole Centrale* and the direction of the school.

Three programs of instruction are offered. The principal one is a general course in electrical engineering occupying one year; a post-graduate program of one year deals with radio communication; and a short course in illumination, occupying about three months, is given in collaboration with the Institute of Applied Optics. For the sake of brevity only the general course is outlined in the following paragraphs. Two classes of students are admitted to the general course. The majority, about two-thirds on the average, are graduates of the higher technical schools, engineers in the State services or *licenciés* of the faculties of sciences, and are admitted by certificate. The remainder of the places are open to competition by *concours.* The student bodies are very mixed in origin and the close association of these diverse and mature groups is one of the happy characteristics of the school. The regular promotions are limited to 200 men, who follow the oral courses and the conferences as a unit, but are divided into three groups for laboratory exercises. The oral courses are also attended by students of the University of Paris who are candidates for a certificate in Industrial Electricity.

The plan of instruction is a particularly happy balance between theoretical courses, conferences with practicing engineers, laboratory and shop exercises, projects and *stages* in important installations. The oral instruction occupies two and a quarter hours of the morning and four hours are devoted to practical exercises five afternoons per week. The two theoretical courses are given by Prof. Janet of the University of Paris and Prof. Chaumat of the *Conservatoire des Arts et Métiers,* both admirable lecturers and thorough-going scientists with what may be called an industrial mentality. The professional conferences, which deal more immediately with applications, are given by twenty notable engineers, mostly in active practice. The school has its own staff of six competent instructors for the practical exercises. The program of lectures and conferences is as follows:

CURRICULUM OF ECOLE SUPÉRIEURE D'ELECTRICITÉ, 1928

Lectures:	
General Electrotechnics (Janet)	60
Electrical Measurements (Chaumat)	40
Conferences:	
Alternating current machines and apparatus	8
Calculation and construction of machines	25
Construction of switchboards	10
Alternating current collector machines	5

Production and distribution of energy	15
Boilers, producers and piston engines	4
Steam turbines	4
Hydraulic installations	4
Regulation of generating groups	1
Storage batteries	4
Mercury rectifiers	2
Underground cables	3
Interior installations	3
Mechanical applications, electric traction	35
Electric equipment of tramway systems	3
Electric furnaces	2
Electrochemistry and electrometallurgy	7
Tests of electrical machines and apparatus	35
Telegraphy	4
Telephony	5
Radio communication	3
Discharges in gases, cathode rays, X-rays	4

Projects:
  Calculation of a continuous current machine
  Design of a continuous current machine
  Design of an alternating machine or appliance
  A project of installation for lighting or distribution
  A project of equipment
Laboratory:
  Measurements and studies of electrical, magnetic and photometric quantities
  Tests of machines and appliances
Shop:
  Construction of an electro-magnet, of splicings and of windings
Stages:
  15 days in generating stations
Excursions:
  11 days in manufacturing plants, power systems and railroads

The Ecole Speciale des Travaux Publics.—Beginning in 1891 with a modest scheme of personal instruction and correspondence teaching for junior members of the *Corps des Ponts et Chausées,* this institution has expanded steadily into the largest and most diversified technical school in France, with 1200 day students and some thousands enrolled in correspondence courses of a higher technical character. The school is an outstanding example of multiple entrance levels, designed to accommodate students of diverse preparation without sacrifice of standards:

COURSES. ECOLE SPECIALE DES TRAVAUX PUBLICS, 1928

Professional Courses	Preparation	Admission
Refrigeration (1 year)	Post-graduate	By certificate
Public Works (2 years)	Math. Spéciales	By concours *
Building Construction (2 years).	Math. Spéciales	By concours *
Electrical Engineering (2 years)	Math. Spéciales	By concours *
Surveying (1 year)	Math. Spéciales	By concours *

Preparatory Courses	Preparation
Public Works	For 3d year, baccalaureate in mathematics
Building Construction	For 2d year, first part of baccalaureate
Electricity	For 1st year, higher primary certificate
Surveying	(Admission is by examination)

* Or from preparatory division by promotion examinations.

The preparatory courses serve the dual purpose of fitting young men who have not taken the program in *mathématiques spéciales* in the *lycées* to enter the higher technical courses and of providing a terminal training for technicians. The higher courses lead to the diploma of *ingénieur* in each of the several specialites and the secondary courses to the certificate of *conducteur.* The curricula of the higher courses are much more specialized than those of the *grandes écoles.* The treatment of mathematics, physics, chemistry and theoretical mechanics is limited more precisely to the needs of distinct groups of engineers; the special and collateral technical courses are closely selected, but a broadening influence is provided by instruction in industrial legislation, commercial law, commercial operations, political economy, industrial finance and accounts, and hygiene. The secondary courses are about equally divided between general subjects—French, mathematics and physical sciences—and technological subjects taught in an elementary and practical manner.

The oral courses, which are given in Paris, occupy the mornings from 8:30 to 11:05. More than two hundred subjects are taught and all courses are put in the students' hands in printed volumes. Practical exercises occupy three hours of each afternoon. The facilities for practical teaching, in the ensemble, are the most extensive in France. The laboratories of materials, hydraulics, heat power, refrigeration, electrical machinery and electrical measurements resemble the substantial American installations and are operated under a similar regime. The shops are of especial interest, since they execute commercial orders for serial production. Accurate time studies and records are made and the accounting operations are conducted as in a small industrial plant. The facilities for field instruction are more extended than in American schools. Correspondence students are encouraged to attend the school of practice in vacation periods for intensive laboratory and field instruction. Much of the school plant has been built by student labor as a form of practical exercise. The school is undoubtedly the most important private educational enterprise in all Europe.

The Institutes of the University of Nancy.—At Nancy a faculty of sciences has reached out most successfully to join hands with its industrial neighbors. The initiative of deans Bichat and Petit has had a happy response from the industries of Lorraine and together they have built up the most important regional center of higher technical education in France, a shining exception in an over-centralized system. Success has been due to creating within the university a flexible group of *instituts* with specific aims and to effective organization of their financial support by the corresponding groups of industries. *Instituts* use to the full the scientific resources of the faculty of sciences, but are not bound by its formal limitations. Each has its own scheme of admission, its own type of program, its own industrial contacts and sources of support, its own director and its special laboratories. Coordination within the university is provided for through the common chairmanship of the dean of the faculty of sciences; and coordination of industrial relations through a *Société des Amis des Instituts Techniques* under the auspices of the *Société Industrielle de l'Est.*

The list of the *instituts* and the dates of their establishment are as follows: Chemistry, 1891; Brewing, 1893; Electrochemistry, 1897; Electrotechnics, 1900; Agriculture, 1901; Colonial, 1902; Dairy Industry, 1903; Mechanical Engineering, 1906; Applied Geology, 1910; and Metallurgy and Mines, 1919. The terms of admission are not uniform and illustrate the flexibility of the system. The institutes of electrotechnics and mechanical engineering admit by *concours* based on one year of work in *mathématiques spéciales;* the institute of metallurgy and mines by *concours* corresponding to the scientific part of the *concours* of *Ecole Polytechnique;* the institute of applied geology admits *licenciés* in geology and graduates of the higher technical schools on credentials; the institute of chemistry admits bachelors in mathematics by an *examen de capacité;* in short, the rule appears to be to put entrance requirements on the highest level the traffic will bear and to raise them as the *institut* advances in age and prestige.

The curricula are organized on much simpler lines than those of the grandes ecoles of Paris. Subjects and courses are grouped together in large units, each with its component of practical exercises, for example:

CURRICULA, INSTITUTES OF ELECTROTECHNICS AND MECHANICAL ENGINEERING UNIVERSITY OF NANCY, 1928

Year I (*Common*)	*Year II* (*Common*)
Mathematics (Calculus, differential equations, applied geometry, kinematics, analytical mechanics)	Physics (Electromagnetism, electrical waves, electrical measurements, direct current electrotechnics)
General Physics (Wave motions, electrostatics, magnetism, thermodynamics)	Applied Mechanics (Elasticity, strength of materials, graphic statics, machine elements, hydraulics)
Mechanical Technology (Metallurgy of iron and steel, shop operations, machine drawing)	

Year III—Electrotechnics

Electrotechnics (Alternating currents, alternating current machinery and systems, illumination, communication, instruments, batteries, electrochemistry)
Electrical Installations (Transmission, distribution, mechanical applications)
Projects of Electrical Design
Tests of Electrical Machinery
Mechanical Engineering (Heat power, hydraulic motors, tests)
Conferences on Accounting

Year III—Mechanical

Hydraulic Machinery (Turbines, pumps compressors, ventilators)
Heat Power (Thermodynamics, boilers, superheaters, economizers, heat balance, steam engines and turbine condensers, governors, gas producers, explosion motors)
Projects of Design (Hydraulic and thermal machines)
Tests of Machinery
Electrotechnics (Machines, installations, tests)
Conferences on Accounting

The curriculum of the institute of chemistry is perhaps the nearest approach in France to the American conception of a course in chemical engineering. The major courses in mineral chemistry, organic chemistry, physical chemistry and analytical chemistry constitute the bases of the curriculum and are carried through two years, accompanied by extensive laboratory work on chemical preparations and analysis. The major course in industrial chemistry covers fuels and metallurgy in the second year and ceramics, coloring matters, dyeing and printing in the third year. Chemical plant and technology are extensively treated in the third year. The necessary complements of mathematics, physics and drawing are taught in the first year, and in the third year selected elements of mechanical engineering, industrial legislation and industrial accounting. The practical exercises of the first half of the third year cover electrochemistry, electrolytic analysis, metallography, tests of mechanical and electrical machinery, and plant design. The laboratory work of the last semester is given over entirely to individual research.

The ensemble of laboratories is one of the best in France, thanks to the generous support of the industries of the region. The institutes of electrotechnics and mechanical engineering are particularly well installed through the personal generosity of M. Ernest Solvay, whose gift of 500,000 francs for this purpose in 1912 was probably the largest individual donation in the history of French technical education.

Free Public Instruction in Technical Sciences

The Conservatoire des Arts et Métiers.—The *Conservatoire* stands in the same relation to the *grandes écoles* of Paris as the *Collège de France* to the Sorbonne. It has a group of professorial chairs for free public instruction in the technical sciences and arts, but has no entrance requirements, no curricula, and no required examinations. Auditors may enroll for a certificate in any subject, in which case a record of satisfactory attendance and a final examination are required. The oral courses, for which no tuition is charged, are given in the evening. There are also practical courses, consisting of conferences, manipulations, drawings and laboratory exercises. given during the day, for which nominal charges are made. Since 1923 a number of grouped courses have been mapped out which lead to the diploma of *Ingénieur du Conservatoire des Arts et Métiers.* Each consists of a major course in some specialty such as mechanical engineering, industrial electricity, metallurgy or aeronautics, together with the annexed course of practical exercises, and three or more minor courses in related subjects in many of which practical exercises are prescribed. The candidate is required to obtain certificates in all of the unit courses, submit to a final written and oral examination before a jury, undergo an industrial *stage* and submit a *travail de concours* or thesis.

The individual courses are largely attended, but there are few candidates for the diploma of *ingénieur.* The lectures in each subject are given on two evenings of the week, the practical exercises on one afternoon. A number of the latter courses extend through two years. There are twenty-three professorial chairs and a number of adjunct professors. Twelve of the chairs deal with branches of engineering and technical science, three with applied art and eight with the economic and social sciences. A series of public conferences is held on Sunday mornings and a series of conference-visits in the museum on Sunday afternoons.

D. TECHNICAL SCHOOLS OF THE MIDDLE CATEGORY

No sharp line can be drawn between the technical schools of the higher and middle categories in France. The *Ecoles d'Arts et Métiers,* although accorded recognition as higher institutions by the Ministry, actually occupy the middle level of scientific and technical instruction. Their genius lies in the realm of the mechanic arts, where they are unsurpassed in Europe. The national schools have served as models to a small group of Catholic schools and to some others under private auspices in Paris, of which the *Ecole Bréguet* is an excellent example. Apart from these groups schools of middle rank are not numerous. Strasbourg has a higher machine construction school on German lines and Mulhouse important schools of chemistry and textile technology; there is a special school for mine foremen at Alais and a school of horology and fine mechanism in the province of Doubs; and the elementary sections for electrotechnics at the universities of Grenoble and Toulouse, for paper technology at Grenoble, and for electrotechnics, public works, building construction and surveying at the *Ecole Speciale des Travaux Publics, du Batiment et de l'Industrie* at Paris practically complete the roster.

Schools of the Practical Arts

The Ecoles Nationales d'Arts et Métiers.—These six institutions constitute one of the most admirable groups, not in France alone but in all Europe. As their essential purpose and character and their methods of admission have already been described, it remains only to consider their internal organization and methods of instruction. In essential matters the six schools are identical. Each serves a defined region, from which a promotion of 100 students is admitted annually. The *concours* of admission, while less intensely contested than that of the *grandes écoles,* is highly selective and assures a competent, homogeneous student body, from which there are few eliminations in course. The school at Paris, which serves only the metropolitan area, takes day students exclusively.

The other five admit boarders at a very low cost. No charge is made for tuition. The students are the pick of the product of the higher primary schools, a strikingly sturdy, hard-working, intelligent and wholesome type.

The course of instruction is three years in length and uniform for all, except for some degree of specialization in shop practice. The program has been worked out by a ministerial commission with great care for the orientation of every item to the central purpose of the schools. The time is divided most systematically. One hour and a half of each morning is given to oral courses and conferences on scientific, technical and economic subjects. An equal period is given to specific technological instruction in shop and drafting room practice and to exercises in drawing and the laboratories. Five hours of the afternoon, excepting one half day given to military instruction and field exercises, are given over to systematic shop training on commercial production. The three divisions of the program are outlined below and the number of lessons or conferences indicated:

PROGRAM OF ÉCOLES D'ARTS ET MÉTIERS

Lectures and Conferences on General Subjects

First Year		Second Year		Third Year	
French	32	Social and industrial legislation	16	Economic history	32
Industrial hygiene	16	Economic geography	32	Scientific management	16
Algebra and analytic geometry	32	Calculus	15	Applied mechanics	34
Trigonometry	14	Descriptive geometry	14	Hydraulics	21
Applied geometry	10	Kinematics	52	Heat power	43
Descriptive geometry	40	General mechanics	18	Industrial electricity	64
Physics (heat)	32	Physics (vibrations)	10		
Chemistry	32	Metallurgy	22		
		Accounting	16		

(Provision is made for seventeen selected laboratory manipulations in industrial physics, chemistry, and metallurgy during the first and second years, and for an unspecified number of measurements and tests in the laboratory of electrotechnics during the third year.)

Lectures and Conferences on Technical Construction

First Year		Second Year		Third Year	
Masonry construction	2	Framed and concrete construction	10	Architecture of machines	5
Carpentry	5	Machine elements	22	Power machines	27
Machine elements	25				

Exercises in Drawing and Design

First Year		Second Year		Third Year	
Conventions	1	Structural framing and assemblies	3	Boiler design	2
Helix, screws, bolts	1	Metal stairway	1	Design of part of a machine tool	1
Machine parts	7	Crank rods, eccentrics	1	Design of a sample structure	2
Wooden framing	1	Pistons and valves	2	Design of a crane or hoist	2
Conic sections	1	Machine-tool parts	2	Design of a steam condenser	1
Graphs of functions	1	Cams and gears	3	Design of a pump	1
Applications of descriptive geometry	3	Applications of descriptive geometry	3	Design of an electric or gas motor	1
Plan of a building	1				

Shop Practice and Conferences

	First Year		Second Year		Third Year	
	Conferences	Weeks of practice	Conferences	Weeks of practice	Conferences	Weeks of practice
Bench and machine work	12	17	10	35*		13
Pattern making	5	6	3	9 } *	1	5
Foundry	5	6	5	26 }	4	5
Forging and heat treatment	6	6	5	35*	5	5
Electrical construction					4	4
Shop office						2
Laboratory testing						1

* Separate sections in the second year.

(The work in the shop office covers scheduling, time studies and records and cost finding. The week of laboratory tests deals with combustion and vaporization, the efficiency of prime movers and mechanisms, and the properties of materials. Electrical construction includes windings, assemblies and shop tests.)

It will be noted that the only provision for specialization is in the shop practice of the second year when the class is divided in the proportions: Bench and tool work, 55 to 80 per cent; pattern making and foundry, 15 to 25 per cent; forging and heat treatment, 5 to 20 per cent. All work done in the shops is for commercial use and up to commercial standards, but the time schedules are adapted to the pace of learners. The work done in the shop offices includes scheduling, time studies and records, and cost keeping. The laboratory tests relate to combustion and vaporization, the efficiency of prime movers and mechanisms, and the properties of materials. The period of electrical construction includes work on windings and assemblies and laboratory tests of generators, motors, transformers and meters.

In scanning the above programs it will be observed that every item has been chosen and directed to a single end—training for intelligent direction of industrial production. This spirit is carried into the individual subjects. The materials in mathematics, physics and chemistry are chosen with a direct view to their engineering utility; the courses are interconnected by problems and illustrations; yet the treatment within its limits is rigorous and in a sound scientific spirit. The work in French consists largely of composition and interpretation of texts, and is tied in with the courses in economic geography and history in the second and third years in the form of monthly written exercises in composition. The relatively great weight given to social and industrial organization will be noted.

The entire treatment of mathematics has a strong geometrical cast. The physics of the first year related entirely to applied heat and changes of state, while that of the second year deals with vibratory and radiant phenomena. The course in chemistry proceeds directly to notions of thermochemistry and chemical equilibrium, then deals with the various raw materials of industry. The laboratory exercises in physics, chemistry and metallurgy deal with such matters as high temperature measurements, tests of calorific power, measurement of gas flow, composition of flue gases, properties of lubricating oils, properties of fuels, dosage of metallurgical operations, analysis and properties of alloys, metallography and welding.

As the program is laid out on a full-time basis, with only the evenings available for preparation and reports, the teaching is necessarily of a very direct character. There is little use of textbooks and much less written work than is customary in American schools. The system assumes that the students will become men of action and execution and not professional scholars.

For the sake of brevity no attempt will be made to describe the equipment of any of the schools. The war caused a great accumulation of modern industrial equipment in France and in the period of readjustment the government was able to modernize and diversify the installations to exceptional advantage. The scale of the plants may be judged from the fact that the shops and their annexes at the Paris school cover a floor space of more than 70,000 square feet. The importance of these schools to French industry may be judged from the fact that they supply between 35 and 40 per cent of the entire recruitment of engineering graduates and more than two thirds of the total supply of mechanical engineers.

L'Ecole Bréguet.—This school is an admirable counterpart to the advanced scientific training of the *Ecole Supérieure d'Electricité.* Established in 1904 on the private initiative of M. Schneider, an industrialist prominently connected with the firm *Maison Bréguet,* it has been of great service to the electrical industries by providing a preparation which parallels that given in the *Ecoles d'Arts et Métiers* for the mechanical industries.

The school comprises an upper division of three years, which may be entered by examination after completing the higher primary school or the first part of the baccalaureate, and a preparatory division of two years. All students in the higher division follow a common program. The curriculum is organized in three parallel groups of studies: (1) theoretical courses in mathematics, physics, chemistry, mechanics and French; (2) technical courses in electrotechnics, mechanics of materials, machine construction, heat engines, hydraulics, machine tools, factory construction, automotive engineering, industrial law and industrial hygiene; and (3) practical exercises in drawing, shop-practice, electrical construction, electrical measurements and testing and diverse applications of electricity. The instruction in mathematics, physics, mechanics and electrotechnics is quite extended on both the theoretical and practical sides, but the collateral subjects are treated in only a general manner. The students work on an all-day schedule, with two afternoons free. More than half of the time is devoted to practical exercises in drawing, design, construction, assembly and testing. An industrial *stage* is required in the summer following the second year. The school year is relatively long, extending from the first week of October to the middle of July, with only brief interim vacations.

The student's progress is checked by individual oral interrogations at intervals of two weeks, by occasional written examinations, by his performance of practical exercises and in the more advanced stages of work by extended projects. Records are made up and remitted to the parents three times each year. A comprehensive examination is given at the end of each year. The student's ranking is based on all his grades in theory and practice and promotion from year to year is determined by a sliding scale, beginning with 10 on a scale of 20 at the end of the first preparatory year and rising to 13 at the end of the second year of the higher division. The diploma of *Ingénieur des Industries Electro-Mechaniques* is awarded only to those who attain a general average of 14 on the work of the two final years. The school has a modest but thoroughly efficient installation carefully designed for its needs. Much equipment is built in its own shops. Graduates who wish to extend their theoretical studies are admitted on certificate to the special advanced section of the *Institut Electrotechnique* at Grenoble or are eligible for the *concours* of the *Ecole Supérieure d'Electricité.*

E. GENERAL OBSERVATIONS AND CONCLUSIONS

Influence of the Organized Profession.—The national organization of French engineers, the *Société des Ingénieurs Civils,* has always maintained a filial relationship to *Ecole Centrale* but has otherwise occupied itself but little with questions of professional education and recruitment. By tradition, the initiative in these matters belongs to the State. The crisis growing out of the immense industrial effort during the late war and the decimation of the ranks of engineers led the *Société* to a most serious and prolonged discussion of higher technical education, which covered considerable parts of 1916 and 1917. The state of education in France and in other leading countries was set forth in a notable paper by M. Guillet,* the eminent metallurgist and Director of *Ecole Centrale,* and the ensuing discussion enlisted a notable group of State officials, educators and engineers. The result of these deliberations was expressed in an extended group of resolutions, which have since exercised a considerable influence on the trend of education. In barest outline, the points made were as follows:

> Revision of secondary education, taking as a base of preparation for engineers the Latin-Science option; strengthening of the experimental sciences; revision of the program of *mathématiques spéciales* to constitute two successive nine-month divisions, leading to a certificate, and the reduction of repeated work.
>
> Maintenance of an orderly regime of work for teachers and students of engineering alike; maintenance of encyclopaedic instruction in the *grandes écoles;* increase of practical exercises, and decrease of *ex cathedra* lectures; closer contact between teachers and students; introduction of treatment of the basic principles of administration; greater emphasis on the economic aspects of the technical branches; larger development of industrial stages; more generous provision for the admission of foreign students and of auditors.
>
> Wider creation of centers of higher specialization, comparable to the *Ecole Supérieure d'Electricité;* introduction of advanced short courses for engineers.
>
> Reduction of military service for engineers to one year, including six months with the colors; more open recruitment of the State technical corps; normal entrance into industry, after military service, at the age of 23.

General Observations.—Generalizations on education by strangers are always of doubtful validity. It is not easy to transmit the facts in due perspective, where differences of language and custom intervene, and far more difficult to catch and interpret the subtler things of the spirit. A critical appraisal should rest on intimate knowledge of a wide range of collateral factors, political, cultural and economic, such as no passing observer can hope to gain. It is plain, however, that the excellences and defects of French technical education are almost the exact reverse of those which characterize the American system. Speaking broadly France is seeking to re-establish a stable economic and social equilibrium; ours is a dynamic equilibrium.

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* *L'Enseignement Technique Supérieure,* Guillet; Soc. des Ing. Civ. de France, Paris, 1917.

France is the outstanding exponent of selection; abstract intellectual processes are pushed to the limit on one hand and practical training in mechanic arts to nearly an equal limit on the other. The intermediate area, in which almost the whole of our effort is concentrated, is but little occupied. French restriction of technical education on the professional level and popularization on the vocational level are the reverse of the traditional American policy. The benefits of selection are patent, but the method seems open to question, even when due allowance is made for differences of national temper, as too abstractly intellectual and alien to the qualities of practical resourcefulness and execution which distinguish the engineer from the savant. Where French selection follows the planes of social cleavage arbitrarily, American zeal for equality works against even a moderate degree of intellectual selection. American technical education is individualistic; it is done for the benefit of the boy, incidentally for industry, and only remotely for the State. French tradition reverses the order; the services of the State are considered first, the needs of industry second, and the benefit of the individual last. Our technical education is extremely decentralized, and, strangely enough, flourishes least in our greatest metropolitan centers; that of France is too much centralized in Paris. Hundreds of youth who might give vitality to the struggling provincial institutes exhaust themselves in futile efforts to force the gates of *Ecole Polytechnique* and other *grandes écoles.*

The French teach humanities, mathematics and science in preparatory schools, and teach engineering theory and practice in professional schools; our preparatory schools are so much given over to social guidance and exploratory processes that our engineering schools are hard pressed to cover the elementary principles. Their technical education is largely in the hands of practicing engineers, ours in the hands of professional educators. We teach by textbook and laboratory, they by lecture and project. The French student excels in mathematical analysis, generalized thinking, precise and logical exposition, and in artistic perception; the American is handy, adept in practical manipulation, thinks concretely, speaks and writes without grace, and senses the esthetic but dimly. The French student has his career plan mapped out in advance, the American works his out catch-as-catch-can. The one works under intense economic pressure, the other with the easy confidence that men are scarce and jobs are plenty. One is trained to create, the other to manufacture and sell.

An outsider is impressed by the prestige of the engineering profession, its important role in the high administrative ranks of State and industry, the personal distinction of its members and the attraction it holds for the best endowed youth of France. He notes the separation between French engineering and research as well as the striking contrast between the fertility of France in technical discovery and its backwardness in industrial exploitation. The French are far from agreement in their appraisal of their own technical education. There is a strong conservative party which desires above all to preserve the traditional France—a self-contained nation, individualistic in temper, intellectually speculative, industrious rather than industrial, given to thrift rather than exploitation, with a balanced economy of peasant agriculture and family-owned industry. To such the present system is acceptable. The opposing party holds that the economic recovery of France, the liquidation of her external debt, the exigencies of defense and the effort to maintain a place of leadership call for greatly augmented industrial production. What this party proposes for technical education is expansion, decentralization, a wider door, greater emphasis on experimental science and research and greater orientation toward industry.

Piecing his scattered impressions together, the observer finds himself drawn to the inference that French technical education produces men of high intellectual valor, but more often a man of reflection than a man of action. The dictum of a Swiss engineer and industrialist of world-wide connections tends to support this inference, ''The chief value of the French engineer is to make original speculations and mathematical analyses,'' which is no more true, perhaps, than most generalizations. The reconstitution of French industry in the past decade goes far to disprove so narrow an appraisal. French educational authorities, however, fully realize that their national genius makes for individual creation rather than standardized production. As an eminent scientist and *Recteur* of a French university expressed it, ''America and France, they are complementary nations!''

PART III. HIGHER TECHNICAL EDUCATION IN ENGLAND AND SCOTLAND

Introductory Resume.—Higher technical education is provided by two types of institutions, the universities and the local technical colleges. The two groups overlap and to some extent interweave, but for the most part there is a fairly distinct and effective division of functions between them. The universities have great independence and are uncompromisingly devoted to the higher intellectual interests of society; they teach the technical sciences in their universal and fundamental aspects and place a large emphasis on research, with the aim of preparing men for work in engineering and industry which requires a high standard of scientific attainment. The local technical schools form the apex of the local units of the public system of education; their activities are closely linked with the daily interests of their local populations and industries; the greater part of their work is done through part-time and evening instruction; and they aim to prepare men for the higher types of practical pursuits. In a number of instances the two functions are combined in one institution which, by affiliation with a local university, serves as a faculty of technical science and provides at the same time the widest range of practical and intensive instruction.

The distinction between an intellectual and a practical emphasis also exists in preparatory education, but is nowhere carried to such extreme limits as in France and Germany. One of the most cherished ideals of British industry is expressed in the phrase "vertical mobility." The technical crafts and professions are not sharply segregated and a continuous ladder of opportunity rises through them all. While precise data are lacking, it is certain that by far the greater part of the recruitment of technical occupations comes from apprenticeship and the local technical schools. The total enrollment of matriculated students of the technical sciences in all of the British universities does not exceed 3,000 and the number of first degrees awarded does not reach 600 per year, while in the London county area alone there are more than 7,500 enrolled in evening and part-time classes in engineering. The total for Great Britain is probably at least four or five times that figure.

While other countries provide for much larger numbers of full-time university students, none approaches Great Britain in providing for such a large proportion of young engineers so adequate a technical education concurrently with self-support and the acquirement of industrial skill and experience through apprenticeship or otherwise. For the great majority economic conditions make some such system the only possibility of gaining a good technical education. It is not to be assumed, moreover, that a part-time technical education is necessarily inferior to a full-time course; it not infrequently

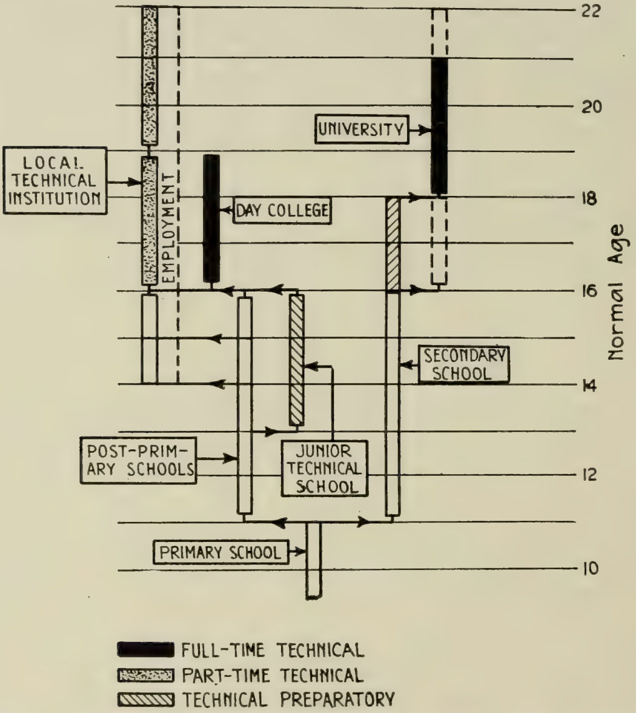
22
20
UNIVERSITY
LOCAL TECHNICAL INSTITUTION
EMPLOYMENT
DAY COLLEGE
18
Normal Age
16
SECONDARY SCHOOL
14
POST-PRIMARY SCHOOLS
JUNIOR TECHNICAL SCHOOL
12
PRIMARY SCHOOL
10
FULL-TIME TECHNICAL
PART-TIME TECHNICAL
TECHNICAL PREPARATORY

Fig. 4. Provision for Technical Education in the English System.

covers 5, 6, or 7 years after the age of 16, with an attendance of perhaps 200 hours per year in evening classes, but the result of diligent work out of classrooms and concurrent experience in industry often carries the student to a standard of knowledge as high as that reached by three years of attendance at a university. There are many highly placed engineers who, quite apart from economic considerations, prefer part-time education to full-time courses as the best possible form of engineering training.

The limitations of evening instruction, even at its best, are severe and there is now a vigorous movement, backed by the national Board of Education, for the wider introduction of part-time day courses to which employers may send engineering apprentices for two or three half-days per week. The number already enrolled exceeds the total of university enrollments in engineering by more than 50 per cent and is increasing rapidly. In the best informed English circles, both private and official, this movement is believed to hold the center of the main highway of educational progress.

A. THE NATIONAL SYSTEMS OF EDUCATION

Education in England.—A distinguished English headmaster recently observed that the chief advance in the first quarter of the twentieth century has been that England as a whole has become converted to a belief in the value of education. England has found her traditional system of voluntary schools inadequate; public responsibility has been accepted in principle and a resolute effort is being made to unify the former chaos into a congruous system. Reorganization is proceeding most actively in the forms of education for adolescents. Secondary education, which was almost wholly a private affair before 1900, has since been greatly extended under public auspices but is still narrowly selective and available for only a small fraction of the youthful population. The university system has been expanded, modernized and made more accessible in the past thirty years and the control has largely passed from ecclesiastical into public hands. The most complete and adequate feature of the entire educational system is undoubtedly the provision for part-time and evening instruction in the local technical institutions.

Education for Adolescents.—The outstanding deficiency of English education has been the totally inadequate provision for the adolescent years. Official reports for 1919–20 showed less than sixty per cent of the age group from 11 to 18 to be receiving either whole- or part-time education and less than six per cent provided for in secondary schools. More recent data, for 1924–25, indicate that out of a total of 100 of English youth attending primary schools 35 continue their full-time education beyond the compulsory lower age limit of 14, but that only 12 of this number enter the secondary school and only 1 the university. These facts emphasize the great importance of higher continuative education and explain the abundant provision made for it in the local technical school which forms the apex of each local school system.

The plan which is now emerging from the former chaos assigns the period between the ages of 5 and 11 plus to the primary school and makes a distinct break at the threshold of adolescence. Here the paths divide: one leads through the secondary school and the university to public life or the distinctly intellectual professions; the other leads through a group of post-primary schools of three types and the higher forms of continuative education into the more practical pursuits.

At the end of the primary period there is to be a careful appraisal of the abilities and interests of the pupils as a basis for their distribution. A large group will then pass to a non-selective ''senior school'' with a three or four years' course; a smaller group to a semi-selective ''central school'' with a four or five years' course; and a much smaller number to a highly selective ''secondary school'' with a six or a seven years' course. The curricula of the senior and central schools are independent of university control and stress modern studies—history and geography, living languages, mathematics and science. Neither school has a distinctive vocational character, but a ''practical bias'' may be introduced in the third or the fourth year. Vocational training in preparation for engineering, trades, or business apprenticeship is given in the ''junior technical school,'' to which the pupil may transfer at the age of 13. The program of the secondary school proper conforms to university standards and is purely non-vocational, but usually has a ''classical'' and a ''modern side,'' which of late have tended to approximate equality of numbers and prestige.

The Scottish Educational System.—Scotland has always been small in population and poor in resources, but nowhere have the benefits of education been more highly valued or more eagerly sought. There is an intensity in Scottish education which England can not match. Scotland has long had a fully articulated system of public primary, secondary, continuation and technical schools and her universities, while autonomous in government, are essentially public institutions. The system as a whole may be pictured as a common base of primary studies extending to the age of 12, from which two ladders ascend to higher levels—one through the secondary school and the university, the other through the upper primary school, the local continuation school and the central institution for advanced day and evening technical studies. In 1924–25 the enrollment in the lower primary schools was 81.7 per cent of the total school population, with 8.7 per cent in the higher primary schools and 9.6 per cent in the secondary schools proper. Again the great importance of higher continuative education for the many denied secondary and university education should be noted.

Local and Central Technical Schools.—The coordination of local and central evening classes is the most distinctive feature of Scottish technical education. The local continuation schools provide instruction in both individual subjects and grouped courses for those who leave the upper primary schools at 14 or 15. The courses extend two years or longer according to the size of the community. The more promising students are transferred at one or more stages to a regional central institution, with travelling expenses paid, for more advanced and specialized work. Three of the five central institutions also conduct day technical colleges where both diploma and degree courses are offered. The evening and day courses are closely coordinated and the evening student of unusual ability may obtain a public bursary to aid him to undertake full-time work. Thus, with wise economy of resources, Scotland has realized Huxley's ideal of "an educational ladder, reaching from the gutter to the university, up which any child may climb as far as his abilities will take him."

The four Scottish universities have distinct chairs or departments of engineering and give considerable instruction on their own account, but the affiliation of the Royal Technical College, Heriot-Watt College and Robert Gordon College with the neighboring universities at Glasgow, Edinburgh and Aberdeen creates an intimate bond between the two systems of higher education. Through reciprocal course schemes the duplication of equipment and instruction is kept to a minimum. The three affiliated colleges, however, do not limit their day instruction to degree courses but cover a most comprehensive field. None of the evening courses are regarded as university work, although some of them reach a relatively high standard.

B. SECONDARY AND POST-PRIMARY EDUCATION

The English Secondary School.—Secondary education in England is represented by two types of schools, the private foundations known as "public schools" and "grammar schools" and a group of more than one thousand schools of more modern origin which are directed by local education authorities and are subsidized by the national Board of Education. The latter are day schools, but in other respects have modelled their life and work as closely as may be after the older boarding schools. The curricula are virtually controlled by examinations set by the universities and fall into two parts: the first normally occupies the period from 11 or

12 to 16 years of age and ends with the ''lower school examination'' which covers the matriculation requirements of the universities; and the second occupies two additional years and ends with the ''higher school examination'' which most of the universities accept in lieu of their own ''intermediate examination.''

There is nothing to prevent the pupil who has successfully passed the lower school examination from passing to the university at this point; in fact, many do so. Those who have shown limited taste and aptitude for scholarship are encouraged to end their formal schooling with the ''leaving certificate'' gained through the lower examination. The majority of those who plan to do university work remain in the secondary school for two additional years, doing intensive preparatory work under semi-tutorial instruction—a plan which fulfills many of the aims of the American junior college. The student majors in a group of closely related subjects and takes one or two minor subjects from other groups. Many reasons contribute to this custom of a prolonged stay in the secondary school. The Board of Education encourages the school to give this advanced work by a subsidy; the schools are eager to hold their better students and athletes; the life is intimate and pleasant, better suited to the boy of 16 or 17 than the more impersonal life of the university; the tutorial instruction accustoms the boy to the methods he will meet in the university; the higher certificate is often required of students entering for the degree with honours; and the intensive work done greatly increases the chances of success in the competitive examinations for the valuable and much coveted ''exhibitions'' and scholarships of the universities.

Example of Secondary Curriculum.—The curriculum shown in Fig. 5 as a type of preparation for university study in engineering is taken from one of the stronger boarding schools. The year-hour totals are based on a schedule of thirty-three periods per week. The preparation in mathematics for the lower examination includes trigonometry, while that for the higher examination includes analytics, calculus and elementary differential equations.

The Lower School Examination.—Prior to 1917 there existed a state of uncorrelated examinations in the secondary schools, each university acting for itself, with resulting confusion and perplexity. The several examining bodies were then brought into closer coordination under an Examinations Council of the Board of Education and a general examination for the lower school certificate was instituted. Its purpose was declared to be "to test the course of general education before the pupil begins such a degree of specialization as is suitable for secondary schools." Five subjects must be taken from the three major groups (1) English studies, including history and literature, (2) foreign languages and (3) science and mathematics, while a fifth may be chosen from a group comprising music, drawing and manual arts. Competent observers have estimated these examinations, most of which are of the essay type occupying three hours per subject, to be of much the same grade as those of the American college en-

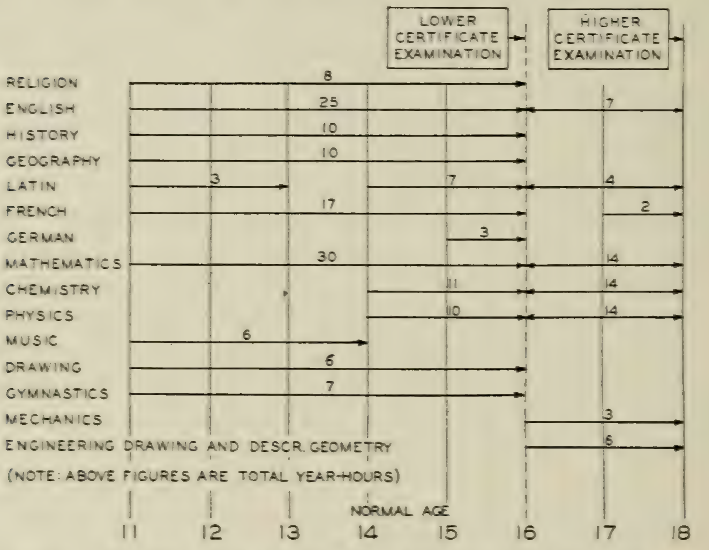

FIG. 5. Typical English Secondary Curriculum, Preparatory to Engineering.

trance board, implying an attainment which few American students reach before the age of 18. The matriculation standard is relatively high; an average of two out of three succeed in reaching it.

Matriculation in Engineering.—For matriculation in a faculty of engineering the candidate would ordinarily be expected to include in his matriculation examination papers in (1) Mathematics (advanced grade), (2) English, (3) a Modern Language, (4) Elementary Physics or Elementary Chemistry or a combination paper on the two, and (5) Geometrical or Mechanical Drawing. The matriculation examination holds a great importance apart from the privilege of university admission, as it is a prerequisite for many of the certifying examinations held by professional institutions and societies and is regarded as an important testimonial by employers. The higher certificate examination implies a much higher degree of specialization and its chief significance is the exemption it carries from the intermediate examination of the university.

Scottish Secondary Education.—The specialization which characterizes the upper period of English secondary education is much deprecated in Scotland; there the entire program is developed as a unit and only one leaving examination is given, commonly at the age of 17. The schools are for the most part public institutions in which all social classes are represented. Four subjects must be passed to gain entrance to the Scottish universities and a higher standard must be met in some subjects than in others. A science or engineering candidate must pass the higher standard in mathematics, he may choose between the higher standard in French or German and the lower standard in Latin or Greek, he must pass in English and may choose between a second language and mechanics.

The Junior Technical School.—The American equivalent of the junior technical school is a vocational high school giving a three years' course preparing for industrial apprenticeship. The course normally covers the period from 13 to 16 years of age. Most of the pupils transfer from the higher primary schools and ex-secondary pupils are rare. Many of the junior technical schools are divisions of local technical institutions and have the use of their extensive laboratory, shop and recreational facilities, but are under the direction of their own principal and staff. There are two quite distinct types of schools, one giving a rather general curriculum in mathematics, science, English, drawing and manual arts preparatory to engineering trades, and the other giving more specific craft instruction, principally for the building trades. In the greater London area there are thirteen junior technical schools with twenty-two different courses in thirteen trade groups. Seven of these schools, with about half of the total enrollment, prepare for the engineering trades. England and Wales had 74 junior technical schools recognized and aided by the Board of Education in 1924–25, with a total enrollment of 10,141.

While these schools prepare for direct entrance to industry, their work is an admirable preparation for the "senior courses" of the technical institutions, where the graduates commonly take the part of pacemakers. As there is no leavening examination to impose an arbitrary standard the better junior schools have shown a refreshing zeal in breaking away from routine academic methods little suited to the mechanically-minded boy. The teaching is very direct; oral, written and practical work are closely interconnected; and new principles are immediately exemplified in the laboratory, shop or drafting room. In mathematics, for example, functional relations and rate concepts are introduced from the beginning and graphical and analytical methods are constantly tied together, so that the student at 16 has some real insight into the nature and practical significance of differentials, derivatives, maxima and minima—an achievement which moves an American observer to mixed envy and despair! English, including history and geography, carries the humanistic load, with French sometimes offered as an alternative to part of the shop-work for those who aim ultimately to reach a matriculation standard. The thirty-hour week of attendance is common, with an additional hour and a half a day of home work. The program of the pre-engineering schools ordinarily gives five clock hours per week to mathematics, physical sciences, English and drawing respectively, six hours to shop work and one to gymnastics. The schools are intimate, the teachers and boys unusually keen and the morale excellent.

Complementary junior courses, consisting of two years of evening work, are given by the local technical schools in order to equalize the preparation of pupils from other forms of post-primary schools before their admission to the senior technical courses.

C. Apprenticeship as an Adjunct to Technical Education

Function of Apprenticeship.—British engineering is an outgrowth of handcraft and technical education is regarded as the modern substitute for part of the mediaeval system of indenture. In keeping with tradition apprenticeship is the common warp which runs through all the processes of technical education and unites them into a common fabric. All the formal processes of teaching and learning from the junior technical school to the postgraduate schools of the universities are regarded as adjuncts to systematic practical training. Individual pupilage, which was once the principal mode of preparation for the professional practice of engineering, is now virtually extinct, but the necessity of practical training is expressly recognized in all official statements of the Board of Education and the professional institutions of engineers and was strongly upheld in the White report * of 1906, which may be regarded as the official charter of professional training for engineering.

The ideal of ''vertical mobility'' has always been dear to British engineers and industrialists, and the scheme of graded apprenticeship with supplementary evening classes in local technical schools is the ladder up which a large proportion of

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* See page 941.

APPRENTICESHIP AND RELATED TECHNICAL EDUCATION IN ELECTRICAL ENGINEERING

Grade of Worker	Previous Education	Duration of Specialized School or College Course in Years	Age on Entry to Works	Period of Training in Works in Years	Subsequent Position in Works	Education Concurrent with Works Training	Duration in Years of Part-time Day or Evening Courses
A. Unskilled and semi-skilled.	Elementary	—	14	Various	Laborers, unskilled and semi-skilled workers.	(*a*) Day Continuation Schools. (*b*) Evening Classes.	2 2 or 3
B. Trade Apprentices.	Elementary	—	14	5 years from age of 16	Skilled workmen in all branches, charge hands, leading hands, inspectors and foremen.	Part-time day or evening courses of Minor grade; or in particular cases of Major grade as below.	2 or 3
	Higher Elementary	—	15–16				
	Junior Technical	2 or 3 years after Elementary.	15–16				
	Secondary	—	16				
C. Engineering Apprentices.	Elementary and Secondary, up to Matriculation Standard.	—	16–18	4 or 5 years from age of 16 or 17	Positions in drawing office, works, test room or on engineering, commercial or erecting staffs.	Part-time day or evening courses for National Certificate in Electrical Engineering: Ordinary grade Ditto: Higher grade.	3 2
D. Student Apprentices.	University or Technical College.	3–4 subsequent to Secondary.	19–22	2 or 3 years for graduates	Foremen, senior positions in drawing office or works, or on engineering, commercial or erecting staffs.	Part-time day or evening courses for National Certificate, Higher grade.	2
E. Research Apprentices.	University	1 year subsequent to graduation.	22	1–2	Staff positions in Research Department of works.		

the ablest engineers have climbed to high responsibility. The universities supply only a fraction, probably between one-tenth and one-fifth, of the higher technical personnel and are constantly pressed to keep their instruction on the highest scientific level. The division of function between apprenticeship, local technical school and university is on the whole a fortunate one.

Forms of Apprenticeship.—An excellent example of the graded apprenticeship system may be taken from the field of electrical engineering.

Internal works schools for trades apprentices are maintained by some of the largest concerns. Engineering apprentices, who are being recruited increasingly from the secondary schools, are expected to extend their education in the local technical schools. An increasing number of concerns are requiring apprentices of this class to attend part-time day classes and pay them at the regular rate for time so occupied. The premium system is not yet extinct, but is moribund. All classes of apprentices now receive nominal wages. Student and research apprentices usually receive about the cost of simple maintenance, but the junior groups who are presumably living at home get much less.

Examples of Apprentice Training.—(*a*) The system of training followed by the Admiralty has many interesting features. Apprentices are chosen by examination between the ages of 15 and 16 and serve five years. In four years of the course they attend special dock-yard schools six hours per week during working hours and six hours on their own time for forty weeks in the year. Annual examinations determine the promotion from year to year. The highest ranking apprentices are sent to the Royal Naval College at Greenwich to be trained as naval constructors and as electrical engineers. The Corps of Naval Constructors, which is probably the most eminent group of its kind, is principally recruited from this source. (*b*) The schedule pursued by student apprentices who enter the Royal Ordnance Factories from the higher technical institutions and universities is fairly representative of industrial practice. It comprises twelve months of machine work, twelve months of fitting, erecting and mill-wright work, nine months in the pattern shop, foundry and forge and three months in the drawing office, with a normal working week of forty-seven working hours.

Order of Practical and Scholastic Training.—No question in the history of British technical education has been debated more heatedly than the order in which the scientific and the practical parts of the training shall be arranged. Strong partisans may be found for each of the following plans (1) works-school, (2) school-works, (3) works-school-works, (4) school-works-school, (5) sandwich and (6) internal school shop for commercial production. All seem to have worked reasonably well. The White report advised that a "preliminary workshop course" of one year should be taken before entering the university or technical day college and the apprenticeship be completed by two years of more specialized experience after graduation. Many of the universities advise and one or two require a year's experience before admission.

The Sandwich Plan.—By this plan the college session occupies the six winter months and the remainder of the year is left free for industrial experience. It originated in Glasgow, where the climatic conditions particularly favor this division of the year, and remains in strong favor with the college and the industries alike. The University of Sheffield offers a similar program as an alternative to its usual course. The University of Bristol has a sandwich plan based on a program of 10 months in college, 14 months in works, 10 months in college, 2 months in works, 10 months in college and a final 14 months in works. Faraday House, a private college of electrical engineering in London, gives a four-year course, the first and third years being spent in college and the second and fourth in practice. Northampton Polytechnic, London, has a four-year course and places its students in co-operating work for six months in the second and third years respectively. The sandwich plan in its purity, however, was characterized by one of its leading exponents as "a plan which enables indentured apprentices to attend college half of the year, something quite unlike the cooperative plan by which the college provides its students with collateral experience."

The Internal Shop School.—Loughborough College is the active exponent of practical training in the internal school shop for commercial production. It gives five-year courses in mechanical, electrical and automobile engineering; during the college session of ten months the student spends alternate weeks in classes and in the production shops, with the option of an additional month of shop experience in the summer. The principal, Dr. Schofield, is an enthusiastic supporter of the plan. The general opinion, however, is that the establishment is too small and too special to give the full equivalent of industrial experience in a normally organized industry.

D. The University Schools of Engineering

Functions of the Universities.—Within the last thirty years the universities have outgrown their traditional scholasticism and have embraced a wide range of academic and professional teaching. There has been no tendency, however, to lump together all sorts of teaching, welfare and service activity at post-secondary age levels or to make the university a mere superstructure of a local system of public schools. Britain knows full well that her civilization can not survive without an aristocracy of intellect. Practical and intensive instruction and welfare activities to meet specific local needs are left in large measure to the local technical colleges, leaving the universities free to serve the higher intellectual interests of society with singleness of purpose. Even where the formal curricula are nearly identical, there is a difference of atmosphere between the universities and the local technical colleges which is unmistakable.

Ripe scholarship of the critical and appreciative type has always been an outstanding quality of English universities, but the systematic pursuit of new knowledge is a comparatively new development. Research is older in the Scottish universities, and engineering research in particular has been prominent from the days of Rankine, Jenkyn and Kelvin. Throughout Great Britain as a whole technical research has been greatly stimulated by the revelation of the recent war that British industry had fallen seriously behind its foreign rivals in the application of science to the solution of industrial problems. The first-aid problems of research belong by rights to industrial research establishments, but the pursuit of new fundamental knowledge remains what it always has been, a field for unhurried, disinterested effort which finds its natural setting in the university. In British judgment it would be the worst possible economy to divert the resources of the universities to the popularization of knowledge or the social digestion of the masses, services which can be rendered at far lower cost and with greater effectiveness by agencies designed for those purposes. The British university both in its teaching and its research bids fair to remain a highly selective institution.

Status of the Universities.—All the universities are public institutions, though wholly autonomous in government. Each exercises its prerogatives by charter from Parliament and is supported in part by grants from the national treasury. The so-called urban universities receive additional grants from local authorities, but none is a municipal institution in the American sense of the term. Only the universities have the right to award degrees. There are many local and independent colleges which prepare students for the ''external degrees'' of the University of London. The term ''college,'' however, does not in itself imply a particular type of institution or standard of instruction. A group of regional institutions of importance which aspire to university status but have not yet attained it are recognized as ''university colleges'' and receive parliamentary grants.

No recent data are available on the sources of income of the universities. Figures for the year 1921–22, exclusive of Oxford and Cambridge, gave 10.3 per cent as the total revenue from endowments, 2.7 per cent from donations and subscriptions, 28.9 per cent from tuition fees, 9.5 per cent from incidental fees and grants, 1.6 per cent from local authorities for special services, 35.3 per cent from treasury grants and 11.7 per cent from annual grants by local authorities.

Character of the Universities.—Oxford and Cambridge still preserve forms of organization which originated at Paris in the 13th century but have long since disappeared from the continental universities. One may trace in academic usages many remnants of the mediaeval guilds and their systems of apprenticeship. The university is in principle a corporation or guild of master scholars, while the colleges are dwelling and workshops combined where a company of masters and their novices share a common life and work. The function of the university is to regulate the system of labor, to test the progress of the novices and to mark their advance to the rank of master by suitable degrees and insignia. With the ancient forms the ancient disciplines were preserved as well. The intimate tutorial regime of the colleges fitted the old scheme of linguistic and mathematical studies admirably, but modern forms of scientific inquiry and professional teaching have demanded central laboratories and a functional scheme of faculties rather than a loose congeries of residential colleges, with the result that the university has come to be a teaching as well as an examining agency. A new departmental organization for that purpose has been superposed on the old system of colleges, and the technical sciences in particular have been made forms of university rather than college teaching. Cambridge has gone much further in this direction than Oxford, but has shown no disposition to create a narrow training school for technicians. Students and teachers are scattered through the colleges and share their life and discipline, while the primacy of disinterested inquiry and the freer forms of teaching have been carefully preserved.

The organization of the Scottish universities and the ''modern'' universities of England is functional, that is by faculties rather than by colleges. By tradition they place far greater emphasis than Oxford and Cambridge of training for professions. The disinterested and intimate spirit of the older universities has had a marked leavening influence. The narrow caste spirit which forced the technical sciences out of the older universities of Germany has never prevailed; on the other hand engineering and technology have never broken away from a close alliance with the pure sciences to become barren utilitarian disciplines.

The University of London is a federal institution comprising thirty-nine internal schools. In addition the University admits to its internal examinations the matriculated students of a group of polytechnics and independent colleges in London which have "recognized teachers." There is a large outer circle of unaffiliated institutions which prepare candidates for the external degrees, awarded by examination only.

The Schools of Engineering and Technology.—The university schools of engineering are comparatively small and few of them have a very distinct identity. Cambridge, which has lately grown to be the largest, has a unified faculty of mechanical science with five university professors and readers, about twenty lecturers and nearly 500 students. Oxford has a single chair of engineering sciences and one reader in thermodynamics, with barely a score of students. The Scottish universities maintain certain chairs of engineering in their faculties of science, but the majority of the students for their degrees receive instruction in the three affiliated colleges which function at the same time as central institutions for non-degree day and evening instruction. Next to Cambridge, the largest university school of engineering in England is the Manchester Municipal College of Technology, which combines the role of the Faculty of Technology of Victoria University with that of the most comprehensive of the local technical institutions. The University of Bristol has similarly affiliated the Merchant Venturers College as its Faculty of Technology, leaving it autonomous in its extensive non-university work. Liverpool and Sheffield have distinct faculties of engineering, and the latter a faculty of metallurgy as well. The universities of Birminghan, Leeds and Durham include their chairs of engineering and technology in general faculties of pure and applied science. The same is true of three of the colleges of the University of London, University, King's and East London; the fourth, the Imperial College of Science and Technology is itself a federation of The Royal College of Science, The Royal School of Mines, and The City and Guilds Engineering College, each of which retains a large degree of autonomy.

Being freed from the entire burden of quantity production, the university schools of applied science are by choice small and intimate institutions. To the British mind this condition seems both natural and desirable. Everywhere one hears misgivings expressed over the American scale of organization, still more of the German, as leading inevitably to "factory methods." The British conceive the highest forms of education in terms of intimate daily contact with distinguished teachers, a corporate life rich in intangible elements, and of training the mind as an instrument of thinking rather than as a process of dispensing information. The small scale of organization makes any high degree of specialization impracticable for teachers and students alike. Nowhere is the distinction between pure and applied science very pronounced and the atmosphere is everywhere one of intellectual training and inquiry rather than one of a formal professional discipline. The continentals have a way of saying that there is no professional education for engineering in Great Britain. This close bond between science and technology is a considerable intellectual asset, but the lack of a marked identity is possibly a handicap to the technical faculties from the viewpoint of practical politics and promotion.

Teaching Corps.—The university professorship is a post of high distinction and appointments are made with the greatest care. As a rule, only the heads of important departments are given this rank, and the titles of associate professor and assistant professor are comparatively rare. The reader and the senior lecturer correspond to our associate professor, the lecturer to our assistant professor, the assistant lecturer and the demonstrator to our recitation and laboratory instructors respectively. When a vacancy of importance occurs it is the custom to advertise it publicly and invite candidates to submit their credentials. This plan gives every man a hearing on his merits and assures the widest possible choice. The result is that appointments are more often filled by transfer between institutions than by promotion. There is a wide gap in seniority and salary between professors and their subordinates. The comparatively small number of professorial chairs —there are probably not more than 100 for all the technical sciences in Great Britain as a whole—makes promotion beyond the rank of lecturer fairly uncertain. The following salary statistics were collected as the basis of a campaign for increases in the intermediate ranks by the Association of University Teachers in 1922. The available information indicates that there has been little change in the interim:

SALARIES OF UNIVERSITY TEACHERS OF SCIENCE AND TECHNOLOGY

Rank	Number	Minimum	Median	Maximum
Professors	209	£500	£950	£1800
Readers, lecturers and assistant professors	509	£200	£450	£900
Assistant lecturers and demonstrators	314	£200	£300	£500

Very few men stood at the maximum level in either group. Slightly more than 20 per cent of the assistant lecturers were above £350, less than 20 per cent of the readers, etc., were above £500 and less than 20 per cent of the professors above £1100.

The scale of salaries for professors, relative to prevailing levels of expenditure, puts most if not all of them beyond the lure of an American appointment, but the group of lecturers offers a promising hunting ground for hard pressed deans and presidents. The men in the higher and middle ranks represent a high degree of learning and scientific capacity. They have relatively little commercial contact with industry and engage only rarely in consulting practice. They have an important share, however, in the coordination of industrial research through the national associations of manufacturers and the professional institutions of engineers, as the institutions are largely represented in the joint commissions by engineering professors.

Levels of Admission.—Secondary and university education in England are essentially a continuous process, marked off into three stages by the lower certificate or matriculation examination, the higher certificate of intermediate examination and the final or degree examination, all of which are given by university authorities. Candidates for degrees may enter the English universities either at the matriculation or at the intermediate level. In any case the minimum period of residence for the bachelor's degree is three academic years, or an equivalent, and the much coveted degree with honours can not usually be gained in less than three years after the intermediate examination. The character of the matriculation examination has been indicated on page 887, and that of the intermediate examination is shown on page 916. The tendency to enter the university at the higher level is plainly increasing; the age of 16 is immature for entrance upon university work, as is 19 or 20 for graduation. Many engineering students, however, take the first year of their practical apprenticeship before entering the university. The universities generally encourage this practice and at least two of them require it. In Scotland, where no higher certificate examination is given in the secondary schools, all degree students enter the university or an affiliated college at the matriculation level and the three examinations which lead up to the engineering degree must be taken in residence.

Many of the university schools of engineering and technology admit non-matriculated students as candidates for diplomas on evidence of their ability to follow the work with profit. The matriculation regulations are fairly inflexible and are thought to work some hardship on fairly mature men who left school before reaching the matriculation standard and have extended their education in connection with their industrial experience. Certain of the universities in the north of England have special regulations covering the admission of candidates over 23 years of age on a personal interview and review of educational attainments, together with such examinations as the Board of Admissions may consider necessary. These institutions also offer an alternative matriculation examination to persons 19 years of age or more with three years of industrial experience supplemented by evening study; four papers are required (1) English composition and literature, (2) an approved modern language, (3) one subject of the ordinary matriculation examination, and (4) an optional subject from a group in engineering technology, economics and accounting.

Forms of Teaching and Examination.—British teaching differs from American chiefly in its greater emphasis on integrated achievement. The system of daily tasks and grades, so common among us, is much less in evidence and far greater weight is given to groups of general examinations. Far from being mere mile-posts in a scheme of progression by the calendar, these examinations are an integral part of the educational process. They represent on one hand British belief in freedom of program and method, on the other definiteness of goal and standard, against our all-too-common rigidity of program, piece-meal collecting of credits and uncertainty of final attainment. In theory, at least, the examinations are primary and the curriculum secondary; in practice, however, great weight is given to an orderly coherent program and to regular performance of work.

One soon gains the impression that there is far more personality in British teaching; the Oxford and Cambridge tradition of master and novice has leavened the whole lump. Lecture teaching is a highly developed art and as supplemented by tutorial work and supervised exercises is scarcely more formal than the American recitation system. Textbook courses are greatly in disfavor. The lecturer develops his subject along general lines and indicates sources of amplification in the literature. Assignments for outside work are largely in the form of problems and exercises. The student is expected to read widely on his own account and is stimulated in this direction by the scholarly atmosphere about him. Laboratory courses are supervised and conducted as with us and consist of assignments of much the same type and magnitude. The professors keep in close touch with laboratory teaching. The classes are small and apparatus abundant enough to admit of synchronism between class and laboratory courses.

The universal thoroughness of the grounding in mathematics, physics, chemistry and elementary mechanics before the intermediate examination affords a wholesome example to practically all American colleges. This solid base permits the teachers of the technical branches to erect their superstructure with only incidental regard for special arts of pedagogy.

Ranking by Examinations.—While the student's ranking is based almost entirely on the results of general examinations, this appraisal is far from being a narrow or routine process. The strictly external examination, except for the London external degree, has virtually disappeared. In all other cases the student is examined by his own teachers or by a jury in which they are well represented. The custom of associating external examiners or assessors with the local faculty, while not strictly universal, introduces a wholesome element of objective judgment. The internal examiners give due weight to the merits of the students' daily performance; in subjects which include practical exercises of calculation, drawing and design, or of laboratory or field work, weight is always given to the exhibits of term work as well as to the written scripts.

Examination questions are set in forms quite like our own. As a rule there are fewer questions or a wider option is allowed. Questions of fact or definition are seldom included.

Topics or problems of a fairly broad and searching quality are presented and the student is judged quite as much by the manner in which he organizes and presents his answers as by the content itself. Evidence abounds that British examination standards are decidedly higher than our own, for pass as well as for honours students. Poor presentation and loose treatment are not passed lightly by easy-going examiners, nor is the student given the benefit of every conceivable doubt or hint of unexpressed knowledge. Comment on American examination standards by British professors with some experience in leading American colleges is far from flattering. The British student, on his side, is less disposed to regard a general examination as a momentary emergency to be surmounted by intensive cramming. The inevitable conclusion to which one is drawn is that the plan makes for thoroughness and integration of effort. The invariable reply of the British teacher to the visitor who raises some question of the validity of the system is "We are well satisfied with the results!" It would be easier to reply if one could say as much of his own.

Honours and Ordinary Degrees.—Many of the universities maintain virtually four parallel but graded levels of work, leading respectively to the degree with first class honours, the degree with second class honours, the ordinary degree and a diploma. The incentive to work on the level of one's highest abilities is strong, as the best opportunities in the academic and industrial world are reserved for the honours men. Deliberately to accept a rating inferior to one's abilities in order to gain a larger share of social or athletic distinctions would be thought bad form.

The honours degree in engineering represents a distinctly higher standard of achievement and a greater degree of independent work, but not as a rule a highly autonomous plan of studies. Even at Cambridge, where the pass student is accepted only on sufferance, the students are required to take all the fundamental courses and specialization is allowed in a very limited degree in the final year only to the ablest men. The specific requirements for honours vary widely from one university to another. Manchester gives a lower three-year course which is entered at the matriculation level and leads to the ordinary degree, and a higher three-year course for the honours degree which is entered at the level of the intermediate examination. The courses at Birmingham are four years in length and normally lead to the degree with honours, the pass degree being given as a concession to students who pass the final examinations below the honours standard. Bristol awards honours for special distinction in its regular final examinations. London requires both a higher standard and additional subjects for honours in the final examinations. At Liverpool and Armstrong (Durham University) no additional time is prescribed for honours, but the candidate must take his final year's work in a so-called honours school, with more advanced work in mathematics and more independent work in the laboratories, and pass a special honours examination. Sheffield requires additional work in pure mathematics, an additional paper on a professional subject and a higher standard in applied mathematics in the final examination. The additional requirement for honours in the Scottish universities calls for one or more additional courses of advanced standard in the final year and a separate final examination for honours. The regulations at Cambridge are outlined in detail on page 913.

The large emphasis on the honours degree detracts somewhat from the pursuit of higher degrees. Candidates with an honours degree can usually obtain the master's degree in one year and the doctorate in two. An additional year in each case would be expected of a candidate with an ordinary degree. Higher degrees are based almost entirely on independent study and research. The professional degree of ''engineer'' is never awarded by a British university, as custom reserves the right to bestow professional credentials exclusively to the chartered professional institutions. The forms in common use in the universities are Bachelor or Master of Science, of Technical Science, or of Engineering. Cambridge bestows the degree of Bachelor of Arts in Mechanical Science.

The degree of Doctor of Science is more common as an earned degree than Doctor of Philosophy or Doctor of Engineering.

Costs and Fees.—The small enrollments in the university schools of engineering and the relatively wide diversity of courses make the unit costs relatively high. In the absence of exact data, the average cost per year per full-time student may be estimated at close to £100. Faraday House, a private college with a four-year course on the sandwich plan, charges 100 guineas per year or £350 for the entire course. Well informed authorities believe that the cost of publicly aided courses does not differ widely from this level. The tuition fees of the English universities are relatively high, ranging from about $200 to $350 per year. Special fees for matriculation, registration, laboratory courses, examinations and degrees add considerably to the total. The fees of the Scottish institutions are somewhat lower; Glasgow, for example charges an inclusive fee of 90 guineas (about $460) for the four sessions of six months each. The London polytechnics offer local students an opportunity to meet the requirements of the University for much lower fees than those of the four internal colleges. Battersea, for example charges £18 per session, as compared with £63 at King's College. Battersea's fee for out-county students, however, is £60 per year. In the residential institutions, such as Oxford and Cambridge, the total of fees and living expenses is seldom less than £200 per year and the average is nearer to £300.

Characteristics of Curricula.—Considering the small size of many of the schools the diversity of curricula is fairly wide. The actual differentiation between the professional branches, however, is quite limited. All groups commonly take the same basic work in mathematics, physics, chemistry, mechanics and engineering drawing, and the amount and character of work in these branches differs but little from one institution to another. In general, the first year is substantially common to all courses and only in the final year is there any marked difference between them. Where the enrollments are small and economy of resources is imperative the electrical and mechanical groups take the same general courses in heat power and electrotechnics and each has its own advanced courses in the final year. British ideals of thoroughness keep the student from straying far from the broad highway of fundamentals into the by-ways of specialization. On the other hand the curricula are relatively narrow; practically all humanistic studies are excluded on the theory that general education is supposed to be concluded in the secondary school; economics is given a restricted place and only its industrial phases are emphasized. The treatment of engineering applications is limited both by time and tradition, since many of the courses are but three years in length and the details of practice are left to the period of apprenticeship.

Technical Curricula in English and Scottish Universities

	Chem. Eng.	Chem. Tech'gy.	Civil or Munic.	Civil and Mech.	Electrical	Eng. Science	Mechanical	Mechan. Science	Metallurgy	Mining	Textile Tech'gy.	Naval Arch.	Marine Eng.
Birmingham [1]			x		x		x		x	x			
Bristol [2]			x		x		x						
Cambridge [3]								x					
Durham (Armstrong)			x		x		x		x	x		x	x
Leeds		x	x		x		x		x	x			
Liverpool			x		x		x		x			x	x
London:													
East London College				x	x								
Imp. Coll. Sci. & Tech.[4]		x	x		x		x		x	x			
King's College [5]				x	x								
University College	x		x		x		x						
Oxford						x							
Manchester		x	x		x		x			x	x		
Sheffield [6]		x	x		x		x		x	x	x		
Aberdeen			x		x		x						
Edinburgh & Heriot-Watt		x	x		x		x		x	x			
Glasgow (Univ.)			x		x		x					x	
Royal Technical College	x	x	x		x		x		x	x	x	x	
St. Andrews				x	x								

[1] Also Oil Engineering.

[2] Also Automobile Engineering.

[3] Options in Civil, Electrical, Mechanical and Aeronautical Engineering.

[4] Also Aeronautics, Technical Optics and Oil Technology.

[5] Also Geology.

[6] Also Glass Technology and Fuel Technology.

Special Emphases.—One of the most striking characteristics is the thorough-going treatment of mechanics and its close integration with mathematics. Mechanics is taught in all cases from the beginning as a branch distinct from general physics. The ability of the student to visualize the basic relations is never taken for granted; one of the most prominent features of every British technical school of any rank is the laboratory of elementary mechanics, fitted out for the experimental verification of the basic principles of statics, dynamics, kinematics and elasticity in semi-engineering forms and magnitudes. As an example of the prominence given to mechanics and of its close integration with mathematics, the syllabus of the common requirements of the City and Guilds Engineering College, London, is reproduced below:

FIRST YEAR COURSE, MATHEMATICS AND MECHANICS, 11 HOURS PER WEEK

Lectures: Abridged arithmetic; the fundamental principles of algebra; theory of indices and logarithms; trigonometry, especially with a view to practical applications and numerical calculations; mensuration of areas and volumes, both graphically and by the aid of algebra and trigonometry, and by aid of planimeters.

The theory of vectors and rotors with applications to statics; elementary solid geometry; introduction to coordinate geometry; introduction to differential and integral calculus and to kinematics and kinetics; graphical statics, the determination of stresses in frames.

Laboratory: Experiments to find the conditions for equilibrium of co-planar forces acting at a point or on a rigid body. Friction. Hooke's law for elongation and torsion of wires and helical springs. Boyle's law. Impact of bodies; experimental determination of the equation of motion of a body under the action of gravity; inclined plane and Atwood's machine. The use of the balance. Specific gravity.

SECOND YEAR COURSE, MATHEMATICS AND MECHANICS, 11 HOURS PER WEEK

Lectures: Coordinate geometry in two dimensions; determinants and the theory of equations; differential and integral calculus with various applications.

Kinetics; the laws of motion and application to the motion of solids and systems of solids. Statics and hydrostatics.

Laboratory: Rotation and oscillation of solids. Determination of moments of inertia by torsional, by bi- and tri-filar suspension. Motion of bodies having translation and rotation. Determination of g by various methods. Experiments on elasticity, deflection of loaded beams, with determination of Young's modulus. Torsion and the determination of the modulus of rigidity. Determination of constants, such as specific gravity, coefficients of friction, coefficients of torsion, etc. Methods of discussing observations, including the method of least squares.

THIRD YEAR COURSE, PURE AND APPLIED MATHEMATICS,
4 HOURS PER WEEK

Lectures and Exercises: Vector algebra; spherical trigonometry; coordinate geometry of three dimensions; differential equations with applications; definite integrals.

Engineering problems of kinematics, dynamics, theory of elasticity, and related subjects.

The laboratory experiments of the first and second years are arranged so as to precede the lectures. The second year course in mathematics and mechanics is paralleled by a common introductory course in engineering which occupies 14 hours per week. This course includes lectures on the strength and elasticity of materials, mechanism, the theory of machines and machine design, the theory of the steam engine, and applications of dynamics; also class exercises and individual experiments in the laboratories of materials and steam engines; design work on simple structures and machine parts; and either laboratory exercises in shop practice to supplement the work in strength of materials and theory of machines, or field exercises in surveying. Further work in mechanics is given in the third year as related to the special problems of civil, mechanical and electrical engineering.

With many variations of detail, this substantial common trunk is characteristic of all British engineering curricula. The close linking up of mathematics and mechanics, of analytical, graphical and experimental procedures and of theory and applications, which contributes greatly to the thoroughness and integration of learning, would be difficult to maintain under the highly departmentalized conditions of teaching which exist in our larger institutions. Hence the universal British disbelief in size as tending to "factory methods."

Examples of University Curricula.—The following are selected examples and analyses of British university curricula in engineering and allied branches of technology:

THE CITY AND GUILDS ENGINEERING COLLEGE (LONDON)

Requirements in Year-Hours

Subject	Year and Curriculum			
	1 All	2 Civil	2 Elec.	2 Mech.
Mathematics and Mechanics:				
a. Lectures	3	2	2	2
b. Exercises	5	3	2	3
c. Laboratory	3	3	3	3
General Chemistry:				
a. Lectures	2	1	1	1
b. Laboratory	4.5	2	2	2
Physics:				
a. Lectures	2			
b. Laboratory	4.5			
Engineering Drawing:				
a. Exercises	3			
Engineering Shop:				
a. Laboratory	3			3
General Engineering:				
a. Lectures		2	2	2
b. Exercises		4	4	4
c. Design		5	4	5
Electrical Engineering:				
a. Lectures		2	2	2
b. Exercises		1	2	1
c. Laboratory		2	5	2
Surveying:				
a. Lectures		1		
b. Field work		2		
Physical Chemistry:				
a. Lecture			1	

The City and Guilds Engineering College (London)

Requirements in Year-Hours

	Year and Curriculum		
	3 Civ.	3 Elec.	3 Mech.
Mathematics:			
a. Lectures	2	2	2
b. Exercises	2	2	2
Works Administration:			
a. Lectures	1/3	1/3	1/3
Materials and Mechanisms:			
a. Lectures	1/3	1	
b. Laboratory	2/3	2	
Geology:			
a. Lecture	2		
b. Laboratory	4		
Thermodynamics:			
a. Lectures		1	
b. Laboratory		2	
Surveying:			
a. Lecture			2/3
b. Field Work			2
c. Drawing and computation			2/3
Civil Engineering Major:			
a. Lectures	6		
b. Drawing and computation	10-1/3		
c. Laboratory	2-1/3		
Electrical Engineering Major:			
a. Lectures		4	1/3*
b. Exercises		3-2/3	
c. Design		3	
d. Laboratory		9	2/3
Mechanical Engineering Major:			
a. Lectures			3
b. Exercises			6
c. Design			6
d. Laboratory			6

Summary of Year-Hours of Attendance

	Civil	Electrical	Mechanical
Lectures	25-2/3	23-1/3	20-1/3
Exercises, drawing, computation	33-1/3†	28-2/3	35-2/3
Laboratory	31	38	33-2/3

* Minor course.

† 3 weeks of surveying camp in addition.

The major courses in civil, electrical and mechanical engineering indicated in the third year above are each of a composite character. Included in the civil engineering major are hydraulics, hydraulic engineering, field engineering and foundations, and structural engineering. The electrical engineering major includes electrical theory and measurements, electrical machines, power and distribution, telephony and telegraphy, and photometry. The major in mechanical engineering includes thermodynamics and heat engines, hydraulic motors and machinery, advanced strength of materials and theory of machines.

The Royal College of Mines (London)

The curricula in Mining and in Metallurgy, which are taken as examples, are arranged on a principle of concentration under which the student takes not more than two major courses per semester. The two programs are identical in the first two years. The table below gives the course titles and the hours of attendance per week.

Courses in Mining and Metallurgy

Year	Semes.			
I	1	Chemistry 24	Mathematics 4	German 2
	2	Physics 15	Mathematics 3	Astrophysics 3
		Mechanics, Kinematics, Machine Drawing 12		
II	1	Mechanics 14	Machine Drawing 9	Graphics 3
			Applied Electricity 4	
	2	Geology 23	App. Electricity 4	Phys. Chemistry 3

Course in Mining

III	1	Principles of Mining 18½	Surveying 9
		Tropical Hygiene ½	Timbering 2
	2	Principles of Mining 13	Mine Surveying 17
IV	1	Metallurgy and Assaying 18	Mining Geology 2
		Mining Machinery 4	Power Generation 6
	2	Dressing of Minerals 18	Mining Geology 3
		Materials and Structures 3	Electric Eng. 6

COURSE IN METALLURGY

III	1	Metallurgy and Assaying 29½	Tropical Hygiene ½
	2	Metallurgy 19½	Furnace Construction 2
		Metallurgical Analysis 2	Dressing of Mins. 6½
IV	1 & 2	Advanced Metallurgy Metallography Fuels and Thermo-metallurgy Refractory Materials	30

THE UNIVERSITY OF CAMBRIDGE

Cambridge sets its requirements in terms of examinations rather than a prescribed curricular scheme. The candidate must first pass the ''previous examination,'' which comprises two languages, including Latin or Greek, either higher mathematics or experimental physics and chemistry, an English essay, and a paper on either a New Testament book of English history. Exemptions are allowed on either the lower or higher school examinations under stated conditions. Three years of residence are required for the degree of Bachelor of Arts in Mechanical Science. The ordinary degree may be obtained by passing examinations in six subjects, at least three of which must be ''principal subjects'' and at least one from each of two groups. Group I consists of ancient and modern languages and of social sciences; Group II includes the following subjects:

Mathematics
Physics
Principles of Chemistry
Applied Chemistry
Metallurgy
Botany
Zoology
Physiology
Geology
Geography
Engineering I
Engineering II
Engineering III
Military Subjects

In addition to the minimum number of principal subjects a choice may be made from certain subsidiary subjects which are announced from time to time. Principal subjects, as a rule, extend through three terms and subsidiary subjects but one term. The examinations come at the end of the several courses and not at a single period.

Engineering I in the above group includes papers on (*a*) practical mathematics, (*b*) engineering physics and properties of materials, (*c*) applied mechanics, and (*d*) an essay on some historical subject in science or engineering. The examination in Engineering II includes three papers, (*a*) applied mechanics (advanced), (b) strength and testing of materials, and (*c*) a choice from a list of seven technical sciences, and (*d*) an essay on some topic dealing with power or industrial processes. Engineering III includes papers on (*a*) mechanical drawing, (*b*) and (*c*) two options in technical sciences not already taken, and (*d*) an essay on a general subject. The student must also show himself competent by reports or trial in the laboratory processes related to the subjects of his examinations.

The degree with honours is gained through a "tripos examination" in which all candidates must pass eight papers, as in Group *A* below.

GROUP *A*, MECHANICAL SCIENCE TRIPOS

Applied Mechanics
Mechanics of Machines and Hydraulics
Theory of Structures
Heat and Heat Engines
Applied Electricity
Chemical and Physical Properties of Materials
Drawing
Essay

The papers of Group *A* consist of questions of ordinary difficulty. Additional papers are set in Group *B* which deal with a wider range of more difficult questions. It is not necessary to take any of the papers of Group *B* to pass the examination, but to obtain the degree with "first class honours" the candidate must acquit himself with "special merit" in two papers from different sub-groups or with "special merit" in one and with "merit" in two others:

GROUP *B*, MECHANICAL SCIENCE TRIPOS

1. Applied Mechanics; Mechanics of Structures
2. Theory of Structures (Civil); Theory of Structures (Mechanical)
3. Heat and Heat Engines
4. Electric Power; Electric Signalling
5. Aeronautics

A candidate for the tripos must first pass the previous examination or obtain an exemption with a high record. He must also pass a qualifying examination in mathematics and general mechanics before the end of his fourth term. Candidates for honours are advised to enter with the higher certificate and to pass the qualifying examination before coming into residence. At the end of the first and the second year the candidate's progress is tested by an ''intercollegiate examination'' in mechanical sciences, the results of which serve the tutors in advising the student whether to proceed to the tripos or to content himself with the ordinary degree.

THE ROYAL TECHNICAL COLLEGE OF GLASGOW

The normal year's session at Glasgow occupies 25 weeks in order that the students may follow the sandwich plan. The degree courses are four years in length and cover the requirements for the three series of university examinations:

SUMMARY OF REQUIREMENTS IN YEAR-HOURS

Subject	Year and Curriculum									
	1 All	2 All	3 C.E.	3 E.E.	3 M.E.	3 Min.	4 C.E.	4 E.E.	4 M.E.	4 Min.
Inorg. Chemistry	5									
Chemical Lab.	3									
Mathematics	5	5					3	3	3	
Physics	5		4	4	4					
Physical Lab.	4.5									
Eng. Drawing	4.5			3	3					
Mechanics		3	3	3	3	3	3	3	3	3
Mechanics Lab.		3								
Hydraulics and Materials Lab.			3		3		6	3	3	3
Graphic Mechanics									3	3
Heat Engines		2		2	2	2^a	2		3	
Heat Engine Lab.		3	3^b	3	3	3^c			6	
Electrical Eng.		2	2	2	2	2		3		
Elec. Eng. Lab.		3	3^b	6	3			6		3
Geology and Mineralogy			2.5			2				2
Geological Lab.			3			2				1
Metallurgy				1^d	1^d	2^a	1			
Metallurgical Lab.				2^e	2^e	3^c				
Fuels				1	1	1				
Fuels Lab.				3^e	3*e*	3^c				
Civil Engineering			2				3			
Civil Eng. Design			2				2			
Civil Eng. Drawing			3				6			
Mining						2				2
Mining Laboratory						10				
Mining Design										8
Mine Surveying										2
Elec. Eng. Design								6		
Mech. Eng. Design									6	
Eng. Production								2	2	
Total Lectures	15	12	15.5	13*f*	13^f	12	15	11	11	10
Total Exercises	12	15	12	15^f	15^f	15	12	15	18	17

Notes: *a*, Option between Heat Engines and Metallurgical Chemistry. *b*, Option between Electrical and Mechanical Engineering Laboratory. *c*, Option between laboratory courses. *d*, Or 2 according to option. *e*, Option between laboratory courses; if metallurgical an additional lecture is required. *f*, or 14, according to option.

A summer term of 10 weeks is required after the second year in Civil Engineering: Graphic Statics, Surveying, and Materials and Construction taken.

THE MANCHESTER MUNICIPAL COLLEGE OF TECHNOLOGY

Two groups of curricula are offered, *lower* and *higher*. The former may be entered at the matriculation level and lead to the ordinary degree; the latter are entered with the higher certificate and lead normally to the honours degree. Both are three years in length. The second and third years of the lower curricula are identical with the first and second years of the higher group. The requirements of the two groups are analyzed below according to the major divisions of subject matter. The allocations between Civil Engineering, Mechanical Engineering and Mechanics and Hydraulics are open to a minor degree of uncertainty:

SUMMARY OF REQUIREMENTS IN TERM-HOURS (3 Terms per Year)

ELECTRICAL ENGINEERING COURSE

	Lower					
	Year 1	Year 2	Year 3	Year 4	Total Lower	Total Higher
		Higher				
Foreign Language	6	6	4		16	10
Economics, Management			2	8	2	10
Mathematics	15	12	8	9	35	29
Physics, Chem., Geol.	34½	3	2		39½	5
Drawing, Graphics	8½	6	3		17½	9
Shopwork	3				3	0
Mechanics, Hydraulics	14½	9	18		41½	37
Electrical Engineering	1	46½	50	44½	97½	141
Other Engineering	2	3	8	3	13	14

MECHANICAL ENGINEERING COURSE

	Lower					
	Year 1	Year 2	Year 3	Year 4	Total Lower	Total Higher
		Higher				
Foreign Language	6	6	4		16	10
Economics, Management		5	3	9	8	17
Mathematics	15	12	8	9	35	29
Physics, Chem., Geol.	30½	12			42½	12
Drawing, Graphics	15	14½			29½	14½
Shopwork	3	2½			5½	2½
Mechanics, Hydraulics	12	8	12		32	20
Mechanical Engineering	1	9	46	30	56	85
Other Engineering	2	12		30	14	32
Electives			6		6	6

MUNICIPAL AND SANITARY ENGINEERING COURSE

	Lower					
	Year 1	Year 2	Year 3	Year 4	Total Lower	Total Higher
		Higher				
Foreign Language	6	6	6		18	12
Economics, Management			2		2	2
Mathematics	15	12	8	3	35	23
Physics, Chem., Geol.	34½	16	5	6	55½	27
Drawing, Graphics	15	3	9		27	12
Mechanics, Hydraulics	9	8	10	15	27	33
Munic. and San. Eng.	8	41	45½	57	94½	143½
Other Engineering	2				2	0

Requirements for the London External Degree.—The degree of Bachelor of Technical Science may be obtained from the University of London by non-resident students who satisfactorily pass three general examinations:

(*a*) The Matriculation Examination, as indicated on page 887;

(*b*) The Intermediate Examination, which covers the same subjects for external and internal students, as follows:

Pure Mathematics (2 papers)
Applied Mathematics (1 paper and 1 practical examination)
Heat, Electricity and Magnetism (1 paper and 1 practical examination)
Engineering Drawing (2 papers)
One of the following:
  Sound and Optics (1 paper and 1 practical examination)
  Chemistry (1 paper and 1 practical examination)
  Geology (1 paper and 1 practical examination)

(*c*) The Final Examination which, for the ordinary degree, includes three subjects in Group *A* and two in Group *B* and, for the degree with honours, three in Group *A* and three in Group *B* with a higher standard:

Group *A*

1. Theory of Machines and Machine Design. (A 3-hour paper and a 3-hour examination in drawing and design.)
2. Theory of Structures and Structural Design. (A 3-hour paper and a 3-hour examination in drawing and design.)
3. Strength and Elasticity of Materials. (Two 3-hour papers.)
4. Electrical Technology. (Two 3-hour papers.)

Group *B*

5. Mechanics of Fluids. (Two 3-hour papers.)
6. Surveying. (Two 3-hour papers and an oral practical examination.)
7. Applied Thermodynamics. (Two 3-hour papers.)
8. Electrical Machinery and Design. (Two 3-hour papers and a 4-hour examination in drawing and design.)
9. Electrical Power Generation and Transmission. (Two 3-hour papers.)

10. Electrical Measurements and Instruments. (Two 3-hour papers.)
11. Telegraphy and Telephony. (Two 3-hour papers.)
12. Advanced Theory of Machines and Machine Design. (Two 3-hour papers.)
13. Advanced Theory of Structures and Structural Design. (Two 3-hour papers.)
14. Advanced Mathematics. (Two 3-hour papers.)

The university authorities certify that the external degree is of the same standard as the internal degree. Candidates for the latter, however, have the advantage of being examined in part by their own teachers and of receiving due consideration for their performance in term time.

E. THE LOCAL TECHNICAL INSTITUTIONS

Status and Functions.—The apex of each local system of schools—municipal, borough or county—is a local technical institution whose chief function is to provide the higher forms of continuative education. There are more than 200 such institutions in England alone. The outstanding quality of these schools is their complete adaptation to local needs. In some small borough one may find the school in a made-over building with the simplest of rooms and equipment, presided over by a single full-time teacher who enlists the part-time service of intelligent local craftsmen and technicians in giving a modest group of evening courses in drawing, elementary science and trade subjects. A large industrial center may boast a vast polytechnic institution with elaborate laboratories, shops and ateliers, a highly qualified professional staff and many auxiliary craft teachers, a wide range of courses from trade to university standards in both day and evening classes, and an enrollment running into the thousands. The London County Council has a fully coordinated group of twenty or more technical schools under its direction, some for specific industries such as printing and building, others of the broadest polytechnic type, the whole covering the entire range of technical instruction from junior to university courses.

This admirable variety is the result of a happy combination of national aid and local direction. Half of the support comes from the national Board of Education, whose inspectors guarantee the efficiency and standards of the schools and exercise an invaluable advisory influence, but the real direction comes from the local education authorities. In many cases there are advisory committees or auxiliary associations representing the local industries. Throughout England, except in the greater London area, each institution is self-contained. The connection between the local continuation schools and the central institutions in Scotland has already been described.

Relations with Universities.—Five technical institutions in large cities, Bristol, Manchester, Aberdeen, Edinburgh and Glasgow, combine the functions of a university faculty of technology and of a local school of continuative education. The same is virtually true of three London polytechnics, Battersea, Northampton and Regent Street, which have "recognized teachers" of the University of London and prepare day students for the "internal degrees." A large number of the larger local institutions which have no formal university affiliations include in their offerings both full-time and evening courses of university type and standard which lead to diplomas or to the external degrees of the University of London. These conditions make it impossible to divide British technical education into sharply defined university and non-university types. The essential difference is often a matter of intangibles—the atmosphere, traditions, corporate life, scholarly tone and research spirit—rather than the course of study. Where the university is independent and uncompromising in its loyalty to intellectual ideals, the local technical college is flexible, responsive to local interests, and adaptable to the student on the level of his conscious practical needs.

While precise data are lacking, the local technical colleges are unquestionably the chief source of recruitment and training for the technical occupations. The total enrollment of men and boys in evening technical schools in England and

Wales for the year 1926–27 was close to 390,000, with an additional 11,000 in day continuation classes and an equal number in junior technical schools. Many of these numbers, of course, were enrolled in trade courses or in relatively elementary subjects. However, there were more than 4,000 engineering apprentices enrolled in part-time day courses and nearly an equal number in full-time post-secondary courses. The work of these schools is rightfully regarded as one of the major factors in British industrial leadership.

Types of Instruction.—The ideal of adaptability to individual and local needs has led to a wide variety of types and levels of instruction, as follows:

FULL-TIME COURSES

- Junior technical schools:
  - Pre-engineering courses
  - Craft courses
- Day technical colleges:
  - Engineering courses
  - Science courses
  - Technological courses

EVENING AND PART-TIME COURSES

- Preparatory courses
- Junior courses
- Minor courses in crafts
- Major courses:

$$\left.\begin{array}{l}\text{Engineering}\\\text{Technological}\end{array}\right\}\left\{\begin{array}{l}\text{Senior}\\\text{Advanced}\end{array}\right.$$

Evening courses in elementary subjects are classed as "preparatory"; the "junior" courses in evening schools are of two years' duration and are suitable for those who left the day school at 14; "senior" courses are of two or three years' duration and are suited to those who have completed a junior course and to those who have left the day school at 15 or 16; "advanced" courses are suited to older students and reach, within the limits covered, the standards of university work. Major courses extend through both the senior and the advanced stages, while minor courses are confined to the senior stage alone. A minor course usually prepares for some skilled craft within an industry while a major course is related to the industry as a whole or to the higher posts in any part of it.

A clear distinction is drawn in Great Britain between engineering courses, which prepare for activities relating to the design, manufacturing and utilization of machinery and to civil construction, and courses in the technology of specific industries, such as textile manufacturing, printing, coal mining and the like.

Examples of the Range of Instruction.—Four examples have been chosen to illustrate the range of instruction offered by the local institutions. The Municipal Technical College of Huddersfield, an important textile and engineering center, is one of the largest schools not affiliated with a neighboring university as a faculty of technology. The Municipal Technical School of Lincoln, a city of about 40,000 with some important manufacturing interests is of much more modest proportions. The Manchester Municipal College of Technology is the most conspicuous, perhaps, of the university affiliated schools as well as the largest and most comprehensive of the local institutions. The London County Council School of Building at Brixton, represents the monotechnic type of institution.

TECHNICAL COURSES OF A LARGE LOCAL INSTITUTION (HUDDERSFIELD)

Major Part-Time and Evening Courses

(S denotes the senior and A the advanced grade.)

Course	Years and Grade	Credentials	Course	Years and Grade	Credentials
Woolen Yarn	3S, 2A	Dip.	Dyeing	4S, 2A	Nat. Cer.
Worsted yarn	3S	C.&G. Cer.	Civil engineering	3S, 2A	
Weaving and designing	3S, 3A	Dip.	Mechanical engineering	3S, 2A	Nat. Cer.
Cloth finishing	4S, 1A	Cer.	Electrical engineering	3S, 2A	Nat. Cer.
Textile mfg.	3S, 3A	Dip.	Building	3S, 2A	Dip.
Loom tuning	4S	Cer.	Plumbing	3S, 2A	Cer.
Chemistry	4S, 3A	Dip.; Deg.	Coal mining	6S, 6A	Dip.
Gas engineering	3S, 2A	Nat. Cer.			

Minor Evening Courses

Breadmaking	3	C.&G. Cer.	Ironfounding	3	Cer.
Confectionery	3	C.&G. Cer.	Woodworking	2	
Mechanical engineering	4	Cer.	Carpentry	3	Cer.
Pattern making	3	Cer.	Electrical workshop	3	Cer.
Motor engineering	4	Cer.	Telephony	4	C.&G. Cer.

Full-Time Day Courses

Chemistry	3	Dip.; Deg.	Electrical engineering	3	Dip.; Deg.
Dyeing	3 or 4	Dip.	Science	3	Dip.; Deg.
Wool textiles	3	Dip.	Architecture	3	Cer.
Civil engineering	3	Dip.; Deg.	Architecture	2 Adv.	Dip.
Mechanical engineering	3	Dip.; Deg.	Commerce	3	Dip.

COURSES GIVEN BY A SMALLER LOCAL INSTITUTION (LINCOLN)

a. Secondary Day School for boys; 7-year course; 380 enrolled.

b. Day and Evening School of Art; 160 enrolled.

c. Part-Time Day School for Mechanical Engineering Apprentices; 2-year course, advanced grade; 67 enrolled.

d. Evening Engineering, Science and Commercial Classes; 800 enrolled.

Mechanical engineering, junior course, 2 years (14–16)
Mechanical engineering, minor course, 2 years (16–18)
Mechanical engineering, senior course, 3 years (16–19)
Mechanical engineering, advanced course, 2 years (19–21)
Motor car engineering, minor course, 1 year
Electrical engineering, senior course, 3 years (16–19)
Telegraphy and telephony, minor course, 1 year
Course for apprentice chemists, 1 year
Matriculation subjects
Subjects for intermediate examination (London)
Junior commercial course, 1 year
Senior commercial course, 3 years

PART-TIME DAY COURSES FOR APPRENTICES

Wood Machine Work, 2 years
Letter Press Composition, 2 years
Machine and Press Work, 2 years
Lithographic Printing, 2 years
Photo-mechanical Processes, 2 years
Book-binding, 2 years
Pharmaceutics, 3 years
Plumbing, 3 years

EVENING COURSES IN CRAFT SUBJECTS

Carpentry and Joinery, 3 years
Cabinet Making, 3 years
Photography, 2 years
Photo-engraving, 2 years
Photo-lithography, 1 year
Typography, 4 years
Machine and Press Work, 4 years
Lithography—Drawing, 4 years
Lithography—Printing, 4 years
Book-binding, 4 years
Breadmaking, 3 years
Flour Confectionery, 3 years
Foundry, 2 years
Plumbing, 5 years
Sanitary Inspection, 3 years
Mine Firemen, 1 year
Mine Undermanagers, 2 years
Mine Managers, 1 year

Summary of Courses, Manchester Municipal College of Technology

Degree or Credentials	Curricula	Basis of Admission	Day or Evening	Length Years	Hours per week
Ph.D.	Elective	B.S. or M.S.	Day	2 (min.)	
M.S. Tech.	Elective	B.S. or special	Day or part time	1 (min.)	
B.S. Tech. Honours: 1st class 2d class 3d class Ordinary	Mech. Eng. Elec. Eng. Mun. & Sanitary Eng. App. Chem. (10 options) Textile industries (5 Options)	Higher certificate for honours Matriculation for ordinary degree	Day	3	26 to 37
Certificate in Technology	Same as for B.S. Tech., also Photography	Entrance examination	Day	3 2	26 to 37 30
Certificate with Distinction	Advanced in above branches	Certificate in Technology	Day	1	
Ordinary National Diploma	Mech. Eng. Elec. Eng.	Min. age 16 and examination	Day	2	28
Non-degree courses	Mun. & Sanitary Eng. Textile Industries Chemistry of Textiles	Min. age 16 and examination	Day	2	27 to 31
Ordinary National Certificate for Senior courses	Mech. Eng. Elec. Eng.	Min. age 16, school certificate and related employment	Day (1 per week) or Evening (3 per week)	2 2	7 6½
	Chemistry and Chem. Technology (6 options)	As above, and 1-year prelim. course	Evening (3 per week)	2	7

Degree or Credentials	Curricula	Basis of Admission	Day or Evening	Length Years	Hours per Week
Associateship and higher National Certificate	Mech. Eng. Elec. Eng. Chemistry and Chem. Technology (6 Options)	Ordinary National Certificate	Day or evening Evening	2 2	7 7
Associateship	Steelwork Reinf. Concr.	Min. age 16, School Certificate and related employment	Day and evening (1 per wk.)	3	9
Intermediate Course Certificate	Munic. Eng. Sanit. Eng. Bldg. Surv. Heat. & Vent. Build. Const. Struct. Eng. Cotton Spin. Cotton Manuf.	Min. age 16, School Certificate and related employment	Evening	2	7
Associateship and Advanced Course Certificates	Munic. Eng. Sanit. Eng. Bldg. Surv. Heat. & Vent. Build. Const. Quant. Surv. Reinf. Concr. Textile Des. Cotton Indus.	Intermediate course as above	Evening	2	7
Certificate	Indus. Adm. Indus. & Soc. Welfare	Evidence of secondary education	Day	2	33

SUMMARY OF COURSES, LONDON COUNTY COUNCIL SCHOOL OF BUILDING

a. Junior Day School. Pre-apprenticeship craft courses, entered at 13:

Brickwork	Plumbing
Masonry	Painting and Decorating
Carpentry and Joinery	Plastering

b. Senior Day School. Course, 3 years; entered at 16, with lower school certificate; technical preparation for leading positions in the building industry; principal subjects are Architecture, Building Construction, Mathematics, Drawing, Chemistry and Physics of Materials, Mechanics of Building, Quantity Surveying, Reinforced Concrete, Structural Engineering.

c. Evening School:

Major courses, preparing for professional examinations, 6 hours per week:

- Building Construction and Drawing, 5 years
- Quantity and Building Surveying, 5 years
- Valuation and Land Surveying, 5 years
- Structural Engineering, 4 years
- Architecture and Drawing, 5 years

Trade courses, each 6 hours per week:

- Brickwork, 3 years
- Masonary, 3 years
- Carpentry and Joinery, 4 years
- Plumbing, Pipe Fitting and Welding, 4 years
- Heating and Ventilating, 2 years
- Plastering, 3 years
- Painting and Decorating, 3 years
- Wood Machine Work, 3 years

Credentials for Non-Degree Courses.—It is practically hopeless for the British student, however promising, to seek employment or advancement ''on his face'' alone; he is certain to be asked for his formal credentials; hence the universal importance attached to ''leaving examinations'' attested by some certifying agency of unquestioned authority. The university degree fulfills this function in its own field, but is very closely guarded. The immense development of other forms of technical education has called forth other appropriate forms of credentials of national significance, which taken together with the university degrees make up a veritable system of educational currency. The weight behind these credentials depends upon the authority which gives or certifies the underlying examinations. The numerous examining agencies fall into five groups (1) the universities, which administer the lower and higher certificate examinations in the secondary schools and examine candidates for degrees; (2) the chartered professional institutions of engineers, chemists, architects, accountants and the like, which examine candidates for their several grades of membership and for other professional certificates; (3) the City and Guilds of London Institute which examines for certificates in various technological crafts, the Royal Society of Arts which examines for certificates in commercial branches, and similar quasi-public agencies; (4) regional associations of educational authorities which provide leaving examinations in junior and minor courses in technical institutions in their areas; and (5) the more important technical colleges, which examine for their own associateships, diplomas and certificates.

The strictly external examination has a strong traditional basis, and is still exemplified by the lower and higher certificate examinations in the secondary schools. The examinations within the universities have tended to become essentially internal, though usually subject to moderation and review by an ''external examiner'' from some other institution. The best teachers feel hampered in their handling of their subjects and unable to fit their teaching to individual needs under the extreme external type; one must do what will ''pay in the examination room'' and there is often failure to take due account of certain qualities of the highest value, such as sustained application and the ability to work independently. The internal examination is admittedly effective in the hands of professional teachers, though lacking in objective quality, but is not considered a sufficient guide for part-time teachers with little training in the arts of teaching and examining. In such cases a syllabus and examination set by an external agency is generally regarded as a necessary guarantee of attainment.

National Certificates and Diplomas.—In recent years a most satisfactory scheme of examinations and credentials has been developed under the joint auspices of the English and Scottish Boards of Education and a group of professional institutions. National Diplomas in Mechanical Engineering, Electrical Engineering, Chemistry, Naval Architecture and Gas Engineering are given for successful examinations following full-time day courses, and National Certificates for examinations following evening and part-time courses. Both are given in two grades, "ordinary" for senior courses and "higher" for advanced courses, and are normally taken in succession. The examinations are held only in schools specially approved as regards equipment, staff and curriculum, but without narrow prescriptions. The papers are set and the books graded by the local teachers but in the final year of the senior and of the advanced courses the teachers are associated with assessors, appointed by the respective professional institutions, who moderate the papers and revise the grading. Credit is given for home work, class work, practical exercises and attendance, as well as for examination grades. The assessors give only nominal attention to the clear cases of success or failure, but review the border line cases with detailed care. The expense of this supervision is met by a nominal examination fee for each student; the cost per paper moderated is about $5 and per script assessed about 25 cents. The success of this plan in combining freedom for the teacher, latitude for the school to fit its courses to local needs and the guarantee of a professional body of the highest repute has been notable. There is an active demand for the extension of the plan into other fields, especially that of building construction.

The plan has been most largely developed in the field of Mechanical Engineering where it was first introduced in 1922. Taking the examinations and awards of the year 1927 as an illustration of the scope and working of the plan in England and Wales:

DATA ON NATIONAL DIPLOMAS AND CERTIFICATES IN MECHANICAL ENGINEERING, 1927

Credentials	Schools approved	Schools participating	Candidates examined	Candidates passed	Passed, per cent
Ordinary certificate....	108	92	1,150	593	51.5
Higher certificate......	52	42	340	239	70.2
Further endorsement...		3	17	17	100.0
Ordinary diploma......	12	6	42	29	69.0
Higher diploma........	7	5	36	31	86.1
			1,689	909	(av.)53.8

As an indication of the relative importance of these credentials, it may be noted that the total number of university degrees in mechanical engineering and mechanical science for England and Wales in 1927 probably did not reach 250.

Certificates in Technology.—The chief certificating agency for craft and technological branches is the City and Guilds of London Institute, maintained, as its name implies, by the ancient "livery companies" which in medieval times regulated craft apprenticeship. Its examinations are wholly "external," but are set and assessed with the advice of committees representing the respective trades, industries, teachers, and schools concerned. The syllabuses are elaborated in considerable detail and exercise a controlling influence on the teaching of technological and trade branches, particularly in the textile field. Most of the examinations are given in two stages, leading to preliminary and full technological certificates, respectively. The prospectus of the Institute lists 99 separate branches for which certificates are granted, 7 of which are of an engineering character and 26 are various branches of textile technology. In 1927 the Institute gave examinations in 85 subjects at 354 examination centers; 11,308 candidates were examined and 7,051 received passing grades. The City and Guilds Institute is the most important certificating agency for teachers of craft subjects. Before the establishment of the National Certificates and National Diplomas its examinations in engineering branches were of much greater importance. The work of the Institute extends throughout the British Empire.

College Diplomas, Certificates and Associateships.—The larger technical colleges prefer to give non-degree graduates credentials which identify them with the local institution rather than some remote examining agency. Three forms are commonly used, the diploma, the certificate and the associateship, but there is no uniformity of usage and each carries the degree of prestige that the name of the college can give it. The Imperial College of Science and Technology, London, makes its associateship the normal objective of its courses and the degree of the University of London an optional auxiliary. Manchester, as shown on page 173, stresses the degree as a primary objective, awards a certificate in technology to nondegree graduates of its day courses, and uses the associateship as a form of local credentials for the advanced evening courses. Loughborough College conducts courses which meet the external degree standard of the University of London and gives a diploma as its primary award and an associateship as an award of lower standard. The Royal Technical College, Glasgow, makes the diploma in engineering science its normal objective, for three-year day courses and the university degree an optional objective after a four-year course. Holders of the diploma who have had approved practical experience, may qualify for the associateship by a fourth year of studies; degree men, with approved practical experience, may qualify for the associateship by presenting an advanced thesis giving evidence of knowledge of methods of research. In short, the university degree, the National Diplomas and Certificates, the City and Guilds Certificates in Technology and the grades of membership of the professional institutions have a definite, nation-wide significance, but other forms of testimonial are of widely variable significance.

Examples of Curricula.—The examples chosen below are from the evening and part-time courses of senior and advanced grade. The full-time day courses, as a rule, do not differ significantly in form from those of the universities:

COURSE IN MECHANICAL ENGINEERING FOR THE NATIONAL CERTIFICATES

(Municipal Technical College, Halifax)

SENIOR COURSE IN MECHANICAL ENGINEERING

Subject	Hours per week		
	First Year	Second Year	Third Year
Practical mathematics	$2\frac{1}{6}$	$2\frac{1}{6}$	$2\frac{1}{6}$
Engineering science	$2\frac{1}{6}$	$2\frac{1}{6}$	$2\frac{1}{6}$
Engineering drawing	$2\frac{1}{6}$	$2\frac{1}{2}$	$2\frac{1}{2}$

ADVANCED COURSE

	Fourth Year	Fifth Year	Sixth Year
Practical mathematics	$2\frac{1}{6}$		
Mechanics and hydraulics	$2\frac{1}{2}$		$2\frac{1}{2}$
Heat engines	$2\frac{1}{2}$	$2\frac{1}{2}$	
Machine design		$2\frac{1}{2}$	
Materials and structures		$2\frac{1}{2}$	
Economics of engineering			$2\frac{1}{6}$
English and French			$2\frac{1}{6}$

The examination for the higher national certificate is taken at the end of the fifth year, but an additional endorsement may be gained by the work of the sixth year, which also completes the preparation for the Associate's examination of the Institution of Mechanical Engineers. The mathematics of the senior course covers selected aspects of algebra, geometry, trigonometry, graphic representation and simple calculus. The advanced course adds certain complements of algebra and trigonometry, but consists mainly of calculus and its engineering applications. Engineering science is a composite course based principally on mechanics and heat, with applications and laboratory exercises on mechanical systems, materials, and simple engines. The technical courses of the advanced period each include their complement of laboratory work or drawing.

COURSE IN ELECTRICAL ENGINEERING FOR THE NATIONAL CERTIFICATES

(Borough Polytechnic Institute, London)

SENIOR COURSE

	Hours per Week		
	First Year	Second Year	Third Year
Practical mathematics	2	2	2
Electricity and magnetism	$2\frac{1}{2}$		
Mechanics and heat	$2\frac{1}{2}$		
Engineering drawing		$2\frac{1}{2}$	
Electrical engineering:			
Units, measurements, d.c. circuits		$2\frac{1}{2}$	
Materials, d.c. machines			$2\frac{1}{2}$
A.C. circuits			$2\frac{1}{2}$

Advanced Course

	Fourth Year	Fifth Year
Practical mathematics	2	
Electrical engineering:		
A.C. machines	2½	
Laboratory	2½	
Calculation of machines		2¼
Generation, transmission, distribution		2¼
Laboratory		2¼
Design or electric traction		x

The 2½ hour sessions in the senior course include a lecture and a period of 1½ hours devoted to practical exercises. Hours for design or electric traction in the fifth year of the advanced course are not assigned, but are subject to arrangement. A sixth year's work is offered and includes two sessions of 2½ hours devoted to lectures on advanced topics and individual problems of research.

Workshop Production Course (Wolverhampton Technical College)

The first three years of the course are divided into four parallel sections for (1) machinists, fitters and toolmakers, (2) foundry workers, (3) sheet metal workers and (4) motor car body builders, respectively. The program for each consists of three items, each occupying one evening session of 2 or 2½ hours per week; one is a course in workshop processes with lectures and practice, the second a shop drawing course with lectures and practice, and the third a course in mathematics, mechanics and selected elements of other sciences. The fourth year of the course is a common advanced section in advanced shop technology, jig and fixture design and an option between (*a*) book-keeping and works records, (*b*) economics of engineering, (*c*) English, and (*d*) steel and reinforced concrete construction. This is the new course which has attracted wide attention.

COURSE IN METALLURGICAL ENGINEERING (Wolverhampton)

SENIOR COURSE

	Hours per Week		
	First Year	Second Year	Third Year
Mathematics	2	2	
Physics	2½	2½	
Inorganic chemistry, with laboratory	2½		
General metallurgy		1	
Engineering workshops		1½	
Engineering science			2¼
Metallurgical laboratory			2½
Foundry processes and drawing			1½
Iron, steel and metallography *or* Fuels and non-ferrous metals			1

ADVANCED COURSE

	Fourth Year	Fifth Year
Workshop sketching and drawing	2	
Metallurgical laboratory	2½	
Engineering laboratory	1½	
Fuels and non-ferrous metals *or* Iron, steel and metallography	1	
Metallurgy, with laboratory		2½
Metallurgical laboratory *		2½
Electrical engineering		2¼

* or on occasion Testing of Materials.

EVENING COURSE IN TEXTILE MANUFACTURE (Royal Technical College, Glasgow)

The first two years of the course, comprising elementary mathematics and drawing, is taken in one of the local affiliated schools. The third year mathematics may be taken in an affiliated school; in addition a course of Physics covering 2½ hours per week is taken in the College. The four final years are taken entirely in the College and prepare for the examinations for the Certificate in Technology of the City and Guilds Institute:

	Hours per Week			
	Fourth Year	Fifth Year	Sixth Year	Seventh Year
Weaving, lectures	2	2	2	2
Weaving, practical	2	2	2	2
Mechanics and laboratory	2½			
Engineering drawing		2½		
or				
School of Art course		2		
Motive power engineering			2	
or				
School of Art course			2	
Applied design				2

COURSE IN GAS ENGINEERING FOR THE NATIONAL CERTIFICATES

(Royal Technical College, Glasgow)

SENIOR COURSE

	Hours per Week		
	First Year	Second Year	Third Year
Mathematics	2	2	
Physics	2		
Engineering drawing	2½		
Inorganic chemistry		6	
Electricity and magnetism			2¾
Mechanics and laboratory			2½
Gas Manufacture			1
Gas supply			1

ADVANCED COURSE

	Fourth Year	Fifth Year
Motive power engineering	2	
Mechanics	2½	
Building construction	2½	
Design of structures		3
Fuels		3
Gas manufacture		1
Gas supply		1

COURSE IN STRUCTURAL ENGINEERING (London C. C. School, Brixton)

	Hours per Week			
	First Year	Second Year	Third Year	Fourth Year
Mathematics	2	2		
Building science	2			
Building construction	2	2		
or				
Structural drawing	2	2		
Mechanics and theory of structures		2		
Theory of structures and strength of materials			2	
Reinforced concrete			2	
Land surveying			2	
Field work in surveying			2	
Structural design				2
At least two options:				
Building construction II				2
Building construction III				2
Land surveying I				2
Land surveying II				2
Field work in surveying				2

The work in mathematics extends into elementary calculus; building science includes selected elements of physics and chemistry; building construction covers work with brick, iron, steel, timber, masonry and concrete, also partitions, roofs, floors, plumbing, etc. The course prepares for examinations held by professional institutions.

PART-TIME DAY COURSE IN MECHANICAL ENGINEERING FOR THE NATIONAL CERTIFICATES (Woolwich Polytechnic)

This course is intended primarily for engineering apprentices, whose employers agree to release them three half days per week for school attendance:

Subject	Hours per Week			
	First Year	Second Year	Third Year	Fourth Year
Heat, sound, optics	3			
Mathematics	4	3	3	4
Theoretical mechanics	2			
English	1	1		
Mechanical drawing		2	2	
Applied mechanics		2		
Chemistry and metallurgy		2		
Electricity and magnetism			2	
Applied mechanics and heat engines			3	
Electrical engineering				2
Strength of materials and heat engines				4

The examination for the ordinary national certificate in mechanical engineering is given at the end of the third year, and the fifth year's work for the higher certificate may be taken in the evening or in special day classes.

Part-time Day Courses.—The value of the type of evening technical instruction illustrated above, covering the entire range of industry and given on a nation-wide basis, is incalculably great. Britain is easily first in the world in training of this character. A century of experience has revealed certain limitations very clearly. There is now a widespread movement, backed by the Board of Education, to increase the number of part-time day classes with attendance made compulsory by employers. Evening class work is essentially voluntary; it must be made popular to draw and hold attendance; it reaches the ambitious rather than the rank and file and trains men to rise above skill rather than to exercise it; and it places on the employer only an indirect responsibility for its support and direction. It is uneconomical to provide expensive laboratory facilities for evening use alone and difficult to maintain an efficient teaching staff solely for this service. Students and part-time teachers who come after a full day's work can not be at their best. Long experience has shown that it is not practicable to expect attendance for more than three evenings and more than a total of seven to eight hours per week; the annual session covers from twenty-five to thirty weeks and the total annual attendance per man averages about 150 hours. Under these conditions the pace of advance is necessarily slow and the program confined within narrow boundaries. With three half days of attendance per week, required by employers, or what is more common—two half days and an evening of voluntary attendance in addition—a gain of 50 per cent or more is realized, making it possible to broaden the work considerably and to do it under far more favorable conditions. For an example, the Woolwich course on page 934 may be compared with the Halifax course on page 928.

Woolwich had 159 such part-time day students in 1927–28; Coventry, an important automotive center, had 390; and the total for England and Wales amounted to 4,314, which considerably exceeded the total number of students of applied science in all the British universities. One leading electrical manufacturing company has deliberately reduced its intake of university graduates and has gradually increased its recruitment of engineering apprentices from the better secondary schools; this group is sent to one of the strongest technical colleges for a part-time day course which leads to the Higher National Certificate; and the most promising are selected, on the basis of their showing both in school and industry, for scholarships which enable them to complete the full university course.

Fees.—With the definite aim of making higher technical education as widely available as possible, the scale of fees charged for part-time and evening courses is very nominal in comparison with the charges for full-time day courses. The London scale for organized evening courses such as the illustrations cited is £1/10 per year's session for residents of the county. Woolwich charges £1 for a full year's session of the part-time day courses. Wolverhampton charges £10/10/0 per year for its full-time day courses, £1/10/0 for its part-time day courses and £1 for its grouped evening courses. Halifax makes a charge of £15 per year for full-time courses and 13½ shillings for a year's session of a grouped evening course. Glasgow charges by the subject in evening courses and the total fees for a course of three evenings per week range from £3 to £4 per year.

Institutions Combining University and Intensive Technical Instruction.—As pointed out before, five important provincial institutions combine the two functions and certain London polytechnics are virtually outposts of the University of London insofar as their full-time day and part of their evening classes are concerned. A considerable number of other institutions offer day instruction of university standard and enable students to qualify for the London external degrees. Success in maintaining both university types and more intensive and practical types of technical instruction in the same institution is due to the fact that each form has attained a strong and stable development independently and that each is held true to its function by external controls. In the mixed institutions the day colleges are invariably smaller in enrollment. It is the almost universal testimony in England that when the situation is dominated by a group of professorial teachers there is a steady drift toward university types and methods, in consequence different teachers are sometimes assigned to full-time and evening classes; the Scottish technical colleges, on the other hand, attach great value to the fact that the same teachers handle day and evening classes and must adapt their teaching to the two types of men. In general, the influence of the national and local educational authorities operates strongly to hold the local institutions true to their special function. In this they are ably seconded by the professional institutions of engineers, chemists and naval architects, and by the national associations representing the technical institutions, their principals and their teachers.

Teachers and Teaching.—Teachers with the actual or virtual rank of university professors constitute a fairly distinct group and have the status, qualifications, salaries, and independence which that position betokens. The general body of teachers in technical institutions, however, have a status practically identical with that of teachers in the nationally aided secondary schools. Their salaries and rates of advancement, conditions of tenure, and retirement privileges are fixed by a national award, known as the Burnham scale, and their duties are regulated by fairly definite schedules. The salaries for fairly responsible posts are somewhat higher, as a rule, than those of university lecturers. Individual treatment, however, is accorded to principals and to heads of departments in the larger institutions which approximates to professorial standards. The actual title of "professor," however, is reserved to men holding university chairs. In general the professorial group are the more scholarly men and the teachers of other types the more actively in touch with industrial practice. Freedom to engage in independent practical work is not assumed, however, and the consent of the authorities must usually be obtained in advance.

The Association of Teachers in Technical Institutions represents the group in negotiations with the national authorities on questions of salary and status and has had a constructive influence on national policy affecting the support and development of technical education. As a direct result of a recent inquiry by the Association and of its representations to the Board of Education, the latter body has lately undertaken two important investigations dealing with the relation of technical education to other forms of education and to industry and commerce.

The usual period of duty for teachers is ten half days per week, counting each evening session as a half day. As a rule, nearly half of the load falls in the evening. The actual teaching load averages about twenty hours per week. Except in the full-time day courses, the home-work expected of students is quite limited in amount—about half the total hours of attendance—and consists largely of problems and practical exercises. The class instruction is necessarily very direct; lecture methods prevail, but the classes are of moderate size and there is enough questioning and discussion to insure that the subject matter has been understood. The teacher must of necessity be a good expositor, with a keen sense of relative values, skilled in condensation and in rapid review. Class, laboratory and drafting room are closely tied together; as a rule each evening's session is devoted to a single subject, combining a lecture and a period of directly related practical exercises. Learning and performance are thus immediately tied together, with a maximum economy of time and effort.

The Summer School for Teachers.—Many of the teachers in local institutions are first recruited through part-time teaching and are themselves products of evening and part-time training enriched by practical experience. To aid in broadening their educational outlook and to give them the aid of intensive coaching on teaching materials and methods, the national Boards of Education have established summer schools which meet annually for a period of three weeks. The session in England is divided equally between the Universities of Birmingham and of Oxford. Special stress is laid at the former on laboratory procedures, for which unusual facilities are available, and at the latter on class-room teaching and broader inspirational matters. The schools are restricted in enrollment; the privilege of attending is often given in recognition of special merit, with expenses paid by the local and national authorities. The inspectors of the Board of Education direct the school; the tutors are the most distinguished university professors of engineering; and the lecturers, as a rule, are men of special eminence in public, industrial and educational life. While the aims of the summer school established in the United States by the Society for the Promotion of Engineering Education are somewhat different, the inspiration and the original model for the undertaking must be credited to the schools at Birmingham and Oxford.

F. Guiding Forces and Ideals

General Observations.—While British technical education still shows its trial-and-error origins, the developments of the past forty years have been orderly and consistent, indicating that harmonious guiding forces and ideals are at work. The course of legislation in the closing years of the last century was largely guided by a voluntary Association for the Promo tion of Technical Education, founded in 1887 and later expanded to include secondary education, which disbanded after its aims had been embodied in the Technical Education Acts of 1889 to 1900. More recently the three associations of technical institutions, principal and teachers, respectively, have been an active force from within, and on the whole a distinctly harmonious one. The English and Scottish boards of education have had a cumulative influence through the devoted work of their inspectors, their advisory services to local institutions, their special studies of educational methods, their reports on training for the major divisions of industry, their surveys of technical education in certain areas, their summer schools for technical teachers, their initiative in promoting part-time day courses for apprentices, and their leadership in establishing the National Diplomas and Certificates—a fine example of central aid cooperating with local direction without bureaucratic interference. Technical education in the universities has been guided by a common tradition rather than by any form of association or bureaucracy. The influence of the engineering profession is discussed in later paragraphs.

It is almost amazing to an American observer, accustomed to our promotional methods and rivalries, that there has been so little competition or friction between the two arms of the educational system, also that there is so little interest in purely local innovations. British belief in common experience as a sure guide is nowhere seen to better advantage. Nowhere does one meet the self-assertive ''educationism'' now so common in America. Schools are not conceived as a mere filling-in experience for otherwise unoccupied years, nor is ingenuity strained to provide new incentives for learning. Nothing seems to minimize pedagogy like a frank assumption that the student wants to learn what the teacher wants to teach. The motivation growing out of concurrent industrial experience is a great advantage. It is striking to observe how little full-time technical education the world's most highly industrial nation can survive and prosper on, provided that little is high-grade and part-time education is universally accessible.

One finds himself compelled to question whether the American slogan of ''universities for everybody'' is either socially or economically sound.

Adjustment to Industry.—The heated debates on technical education do not center on details of schooling, but on the time and form of practical training, a matter on which American tongues and pens are strangely silent. Apparently we still cling to the pioneer's faith in the ability of the clever man to improvise. There is perhaps a deeper cleavage. To understand British technical education one must understand British industry, which is ''a tall order.'' It is apparent, even to the uninitiated that the traditional reliance of British industry has been on technically intelligent, highly skilled, widely experienced, relatively cheap man-power, rather than automatic or standardized machine process. The hierarchy of research scientists and highly specialized design experts which has made German industry admired and feared, and has more recently established itself in our own, has penetrated into British industry more slowly. The same is true of industrial standardization and of the horizontal and vertical mergers in which modern management finds its most fertile field. Because of the close bond of engineering with handcraft the British engineer has been content to claim a more limited field of responsibility than his American or French colleague, that is he is less often found in finance, sales, purchasing, insurance or in purely administrative posts. British technical education has felt more need, on one hand, to be thorough than to be broad, and on the other, to train generalists rather than specialists. The central place of a few basic fundamentals holds good from the junior technical course to the post-graduate school of the university.

Influence of the Profession.—The engineering profession of Great Britain is a self-regulated body. By universal acceptance the credentials of the several national institutions of engineers stand in lieu of any form of public licensure; while membership in any of these bodies is optional, there is little recognition of professional standing apart from it. The corporate members of the chartered institutions are entitled to sign themselves as "chartered civil engineer," "chartered mechanical engineer," etc. The requirements for admission to membership exercise a very direct influence on the curricula and standards of the various technical schools, and the recommendations which have been made from time to time concerning the training of engineers have had an almost mandatory force.

Report of the White Committee.—In 1903 the Institution of Civil Engineers, with the collaboration of nine other professional institutions, appointed a committee under the chairmanship of Sir William White:

> "To consider and report—as to the best methods of training for all classes of engineers; including both scholastic and subsequent technical education, it being an instruction to this Committee that the principle shall be maintained that the education of the engineer must include both practical experience and scientific training."

The inquiries of the Committee covered preparatory, practical, undergraduate and post-graduate training. Opinions were invited from several hundred engineers, industrialists and educators through carefully drawn questionnaires. On the basis of the returns and its own deliberations, the Committee formulated a group of recommendations in substance as follows:*

1. Preparatory education should end normally at about the age of 17 with a leaving examination equivalent to the Institution's Studentship Examination and acceptable for matriculation in the higher institutions. Modern subjects should be emphasized; an elementary knowledge of Latin is desirable; but modern languages should be taught colloquially. The instruction in mathematics should have in view its practical uses. It is preferable to attain to a general knowledge of elementary physics and chemistry than to pursue some particular branch of science in detail. Special attention should be given to drawing, but handcraft work should be encouraged as a recreation rather than as a school exercise.

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* Reprint of the Committee's Report, William Clowes and Sons, Ltd., London, 1921.

2. The practical training should be divided into two parts, an introductory workshop course of at least one year, to be included for all branches of engineering, and a later period of two years of specialized training. Whatever practicable, the introductory part should precede college or university training and the specialized training should follow. It is highly desirable that part of this practical training should be obtained in drawing offices. During the practical training students should be treated like ordinary apprentices. Where college training is completed before practical training is taken, the total period devoted to the latter should be three years in ordinary cases.

3. For the average student the period of college study should be three annual sessions. A fourth year might be added for those who desire to follow up the science of their profession, as post-graduate work, and might come after the practical training is completed. In all cases the first year's session might be advantageously devoted to a common course of study and probably that common course might be extended into the second year without loss to the final specialization.

4. Sufficient time should be allotted to pure mathematics to permit the best students to obtain a sound knowledge of algebra, trigonometry, analytical and practical plane geometry, the elements of solid analytic geometry, and a working knowledge of differential and integral calculus and of the simpler differential equations. To this fundamental mathematical training must be added instruction in applied mathematics and mechanics. The capacity for acquiring mathematical knowledge varies greatly in individual students and many who become competent engineers have not the power of acquiring the higher mathematics. These differences of actual requirements and individual capacity must be recognized in the courses of instruction. In the later terms of the college course time devoted to purely mathematical instruction should be lessened and that given to specialized instruction in engineering subjects should be increased. The most advantageous arrangements will consist in the combination of mathematical and engineering instruction by the professors and teachers of

engineering. Teachers of pure mathematics should be well informed as to the applications of mathematics in engineering.

5. Efficient instruction in engineering drawing, instruction in testing materials and structures and in the principles underlying metallurgical processes, and other practical operations incidental to the branch of engineering in which the student proposes to specialize, should be included in the college course. Boys who have spent one or two years in mechanical workshops should not be instructed in workshop practice at technical colleges.

6. In connection with the grant of diplomas, degrees and certificate to engineering students, considerable importance should be attached to experimental work performed by individual students, as well as to their progress in mathematical and scientific studies, and degrees should not be granted on the results of final examinations alone.

7. Facilities for post-graduate work by engineering students should be considerably increased, with the special object of encouraging qualified students to undertake researches which may prove of practical value to engineering operations and processes. In many cases the best period for post-graduate work would be that following the completion of practical training, even when that training follows the college course.

8. The sympathetic assistance of employers is essential to improvement in engineering education and training.

The Professional Examinations of the Institutions.—The professional institutions, in consideration of their self-regulatory powers, accept the responsibility for maintaining definite standards of professional competency through (1) examinations designed to test the scientific attainments of candidates (2) prescribed minimum periods of practical training and experience and (3) testimonials of competency from recognized engineers.

The professional examinations are usually given in two grades. The ''studentship examination'' corresponds very closely to the matriculation examinations of the university schools of engineering and exemptions are granted to men who have passed the latter. The "associate membership examination" presupposes a much higher degree of maturity and attainment; for example, the requirements set by the Institution of Civil Engineers are as follows:

ASSOCIATE MEMBERSHIP EXAMINATION, INSTITUTION OF CIVIL ENGINEERS

a. Age of candidate, not less than 21 or more than 26

b. Preliminary or studentship examination passed or exemption obtained

c. Practical training as prescribed in the by-laws completed or definitely arranged for (3 to 5 years required)

d. Written examination, seven papers of three hours each, as follows:

- Section A: (1) Mechanics; (2) Strength and Elasticity of Materials and (3) *either* (a) Theory of Structures *or* (b) Theory of Electricity and Magnetism
- Section B: (4) and (5), Two of the following nine subjects, not more than one from each group:
  - Group 1: Geodesy; Theory of Heat Engines; Thermo- and Electro-Chemistry
  - Group 2: Hydraulics; Theory of Machines; Metallurgy
  - Group 3: Geology and Mineralogy; Stability and Resistance of Ships; Applications of Electricity
- Section C: (6) Engineering Drawing; Specifications and Quantities and (7) a Modern Foreign Language

The Institution recognizes certain degrees in engineering, granted by universities in Great Britain, Ireland and British dominions, as exempting candidates from the examinations of Sections A and B. All candidates, however, must take Section C.

The associate membership examination of the Institution of Mechanical Engineers also includes seven papers. A Modern Language, Applied Mathematics (Mechanics), Physics and Chemistry, Theory of Machines and Machine Design, Properties and Strength of Materials, and Economics of Engineering are obligatory and one may be chosen from the following alternatives, viz., Steam, and Steam Engine; Internal Combustion Engines, Hydraulics and Hydraulic Machines, Electrotechnics and the Mechanical Design of Electrical Machines, and Metallurgy. Exemptions are granted to the holders of certain recognized degrees, diplomas and certificates for all papers except Economics of Engineering, which must be written by all candidates.

The Institution of Electrical Engineers requires five papers, but grants full exemptions to holders of degrees in electrical engineering from any university in the British Empire and to holders of diplomas and certificates from certain recognized institutions.

This system of professional examinations, in effect, fixes the qualifying levels of scientific knowledge for professional standing on a par with university standards, but equalizes the recognition given to university and non-university men. These examinations, or the exemptions obtained for recognized equivalents, are so nearly obligatory on young aspirants that they exercise a marked influence on the courses and standards of all types of technical schools. The institutions of mechanical and electrical engineers grant partial exemptions from their associateship examinations to holders of the Higher National Certificates.

G. SUMMARY OF SIGNIFICANT FEATURES

The distinctive excellences of British technical education stand forth clearly, with significant lessons for our own which need no pointing out: (1) the freeing of the universities from the burdens of quantity production, social assimilation and service teaching in order to serve the intellectual needs of society with singleness of purpose; (2) the abundance and excellence of the provision for these other and equally worthy ends through institutions highly responsive to individual and local needs; (3) effective provision for education in the technology of specific industries as well as in engineering; (4) concentration on fundamentals, integration of teaching and thoroughness of standards in all grades of schools and programs; (5) insistence on practical training and systematic provision for it in all branches of industry and public works; (6) the provision of varied educational credentials, under national sanctions, so that the university degree is safeguarded from inflation and other forms of attainment have due recognition; (7) the controlling influence of the engineering profession on educational standards, without undue encroachment on the freedom of school or teacher; (8) the integrating influence of the national governments, without bureaucratic invasion of university autonomy or of local direction for technical institutions; and (9) the ideal of vertical mobility which has kept caste out of the technical callings and has inspired the ambitious to rise through education to the limits of their ability.

The high importance which Britain attaches to technical education in the present critical period of economic readjustment is revealed in the report of the Balfour Committee, appointed by the Cabinet to inquire into the conditions and prospects of British industry and commerce, on ''Factors in Industrial and Commercial Efficiency.'' Here technical education is given equal ranking with the industrial structure, standardization, scientific research, industrial art, economic measures by the State, and the scale of profits, taxes and transportation charges. A brighter day will dawn for American technical education when leaders of industry and State give it equal recognition.

PART IV. HIGHER TECHNICAL EDUCATION IN CENTRAL EUROPE

Scope of Treatment.—The organization and quality of higher technical education are notably uniform throughout the Germanic and Scandinavian regions, and their influence is plainly evident in the Slavic lands to the east and south. For simplicity one national system, that of Germany, is outlined in considerable detail, and only salient features of other systems are touched upon.

Post-War Changes.—One turns with a sense of relief from the complexities of French and British technical education to the orderly simplicity of Central Europe. He reflects, however, that human nature is not so simple and uniform and finds a more democratic spirit breaking down some of the neat but artificial regimentation of education under the old regime. While class distinctions have been much reduced in the German schools, they still persist under stress of economic pressure to a much greater degree than in richer and less cramped countries like Holland and Sweden. The main frame-work of the educational structure bids fair to stand, but with far wider latitude of individual adjustment within it. A striking example is the appearance in the German university of the partially self-supporting student, unknown before the War. The German secondary school remains a selective institution for intellectual nurture, but a fourth type has been added to emphasize modern culture as distinct from the older classical and scientific disciplines. The higher industrial schools are now open to graduates of the *volkschulen* who have completed their preparation in continuation schools, as well as students from the secondary schools. Central Europe is both crowded and poor, and economic necessity bends the individual to the common interest in spite of democratic ideals. Technical education, at the bottom, is still what it was, a strongly organized arm of national industrial systems, operated with only secondary concern for individual welfare or privilege.

A. General Organization of German Education

Levels of Technical Education.—Higher technical education in Germany stands on three clearly defined levels, viz., (1) the technical universities, (2) the higher industrial schools and (3) the middle industrial school. The more elementary forms are included in the continuation schools and trade schools. The universities may be approached only through the complete nine-year program of the secondary schools, terminating with the maturity certificate; they devote themselves exclusively to the more advanced forms of teaching and research, and send their graduates forth as fully accredited members of the technical professions. The higher industrial schools are approached normally through a six-year program of secondary studies followed by two years or more of carefully selected industrial experience or, as an alternative, four years of experience and continuation study following the

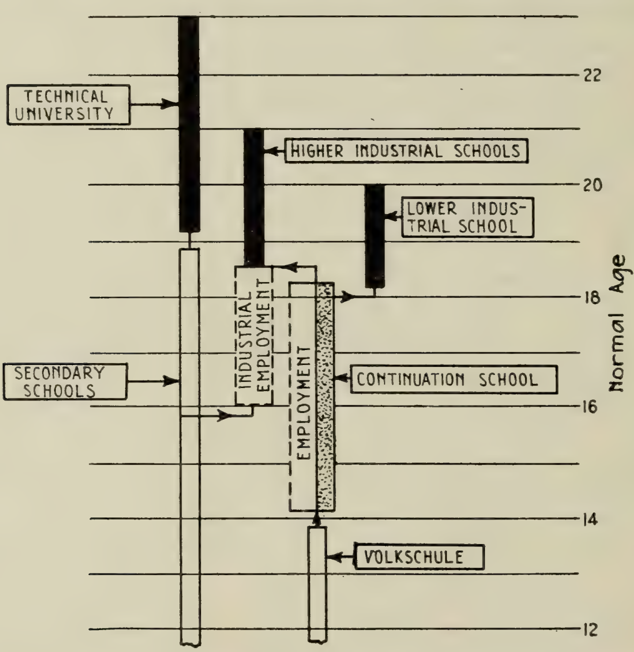

TECHNICAL UNIVERSITY
HIGHER INDUSTRIAL SCHOOLS
LOWER INDUSTRIAL SCHOOL
INDUSTRIAL EMPLOYMENT
EMPLOYMENT
SECONDARY SCHOOLS
CONTINUATION SCHOOL
VOLKSCHULE
22
20
18
16
14
12
Normal Age

Fig. 6. Technical Schools in the German Educational System.

volkschule. Their graduates are prepared for the higher practical pursuits of industry, construction and engineering, and they may qualify for full professional recognition after five years. The middle industrial schools are approached through four years of continuation education and experience following the *volkschulen* and train the intermediate technicians and supervisors of industry. These three levels are characteristic of all Central Europe and Scandinavia.

Elementary Schools.—Families are free in theory to choose either an intellectual or a practical education for their children, but economic necessity commonly dictates a choice in keeping with the status of the family. As there is little or no place in the social order for persons with no specific training, a choice must be made which will lead in a pre-determined time to a vocation and ultimately to self-dependence. Secondary education does not in itself lead to any vocation; it is strictly a form of intellectual preparation for higher study. Practically, the only choice lies between the *volkschule* with its fixed terminal point at 14 and the secondary school followed by some form of higher education ending at 21 or 23. Class distinctions, however, have been effectively wiped out of elementary education, and the *vorschule* now serves all groups up to the age of 10, when the paths divide.

Continuation Schools.—The *volkschule* provides a fairly utilitarian education ending at 14, when the pupil enters employment as a *lehrling* and continues his education one day each week for three or four years in a compulsory *fortbildung-schule* or continuation school, one of the most distinctive features of the German educational system. The larger cities maintain separate schools for related groups of occupations. In Hamburg, for example, there is an admirable modern school for all groups concerned with the production and supply of food products where grocer's boys, baker's helpers, apprentice waiters, etc., follow distinct courses built up around their specific needs and interests. Industrial concerns are encouraged to maintain internal works schools for apprentices, subject to public regulation. Excellent examples may be seen at the Blohm and Voss shipyards in Hamburg, the German General Electric Company's works at Berlin, and at Sulzer Brothers in Winterthur, Switzerland. The technical instruction, which bears directly on the special industry, is supplemented by courses in German and civics, and by many admirable recreational and welfare features. The more promising boys in technical pursuits are prepared for entrance at 18 into the middle industrial schools, which give a two-year full-time program. Others who aim still higher, may qualify by supplementary evening classes for the entrance examinations of the higher industrial schools.

Types of Secondary Schools.—The democratic influences of recent years have widened the paths of access to secondary education without changing its essential quality. The tuition charges are scaled to the means of the family and in cases of need are remitted entirely. The system is still essentially selective; education is still an exacting intellectual process and not a sentimental privilege. Three types of secondary schools with nine-year programs have the highest standing and privileges. The *gymnasium* emphasizes Latin and Greek; the *realgymnasium,* Latin in combination with modern languages and to a less degree science; and the *oberrealschule,* science, mathematics and modern languages. There are also six-year secondary schools which carry the boy only to the *obersecunda* grade. Formerly this grade had a very special significance, for boys who passed the examination were classed as *einjähriger,* that is, they were required to render only a year of military service and might do so as "volunteers" in a regiment of their choice. Today the *obersecunda reife* is of value chiefly in qualifying the boy for admission, after two years or more of carefully chosen industrial experience, to one of the higher industrial schools. To the older types of secondary schools, a fourth, dealing mainly with German culture and modern languages, is now being added.

Secondary Curricula.—The programs of the three older schools contain a large proportion of identical work, but the differences of aim and emphasis are so clearly visualized that the schools continue to be distinct after the historical causes have been forgotten. The aims of each type are clearly set forth by the State authorities, the course of studies is fixed in outline by a simple plan of subjects and time assignments, and the rest is left to the teachers. The curriculum includes but few subjects and these are largely continuous through the nine-year program. The schools are fairly small, with an average enrollment under 500 and the staffs are practically permanent. All these conditions make for intimacy and continuity.

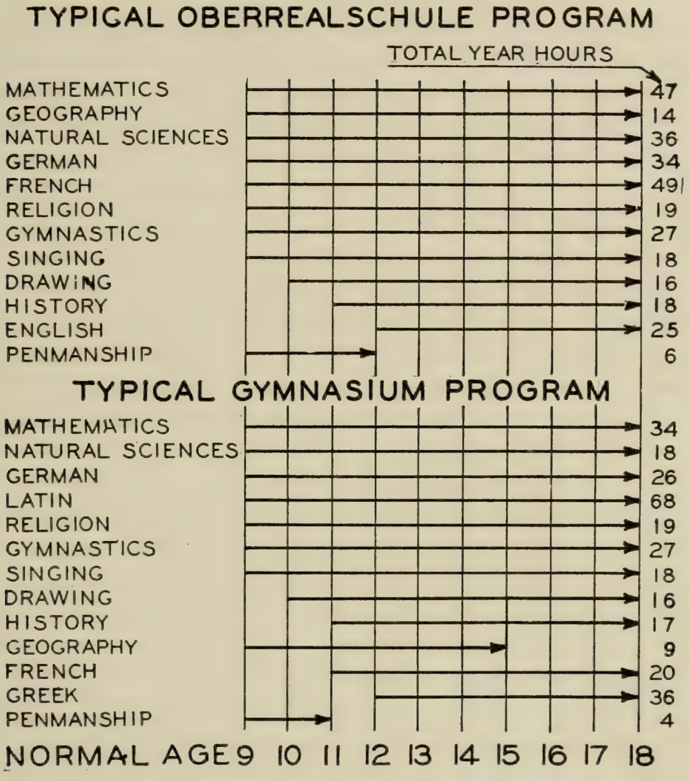


Fig. 7. Typical Curricula of German Secondary School.

The spirit and aim of the German secondary school may be judged by the statement of the ideals for the teaching of the natural sciences which appears in the official manual for the schools of Prussia:

> ''The task set for each branch compels the intimate interlocking of them all into a single course in science. The individual school must determine the separate ends to be sought, but the interrelation of all branches with the entire curriculum will condition the formulation of the course.''

Teachers and Teaching.—The excellence of German secondary education owes more to its corps of teachers than to any other factor. In order to qualify for appointment it is necessary to pursue four years of study in a closely related group of studies in an academic or technical university, serve a two-year apprenticeship and pass preliminary and final examinations. Teachers in secondary schools and universities are required to have an equal scholarly preparation, but men seldom pass from one to the other group since secondary teachers are more often distinguished by pedagogic qualifications and university teachers for their specialized researches. Secondary teachers are not allowed to assume the title of professor, but have their own mark of special distinction in the title of *studienrat.*

The teaching processes involve a fairly continuous give-and-take in the classroom. There is less lecturing and less copying verbatim that in a French *lycée.* The teacher unfolds the subject and skillfully draws first one, then another, pupil into the process of developing it and cross-tying it with all related matters. There is a good deal of book work, but it follows rather than precedes discussion in class. In the three final years the student is gradually prepared for the more formal and impersonal methods of teaching he will meet in the university. In the *oberrealschule* particularly there is constant drill in mathematics and a comparatively generous allotment of time to experimental science. Only men teachers are found in the schools for boys. Many of them are *diplom-ingenieure* trained in the technical universities and the best of counselors and guides to young men looking forward to the technical professions. School plants, as a rule, are of a simple but sustantial character. The laboratory equipment is modest, but admirably chosen and used with notable efficiency. The *de luxe* show features of American high schools are completely absent, but the compensation and status of teachers are relatively much higher.

Admission to Higher Institutions.—The nine-year secondary courses end with the State *abturient* or maturity examination, an ordeal of some moment, though less feared than the French *baccalauréat.* The maturity certificate of any course will gain admission to the technical university, but the student coming from the *oberrealschule* has a marked advantage in his more extended preparation in mathematics and science. The *gymnasium* graduate is nominally on a par with the American student at the end of his first year in one of the better engineering colleges, the *oberrealschule* graduate with an American at the end of his sophomore year. It is difficult to establish a qualitative equivalence since German standards are notably homogeneous and American standards notoriously variable. The boy who leaves the *realschule* at 16, with his *obersecunda* examination passed has covered much the same ground in mathematics and science as the American high school graduate. The levels of entrance to the higher industrial schools are but little inferior to those of the average American engineering college, plus the added maturity of two years of experience. The technical universities place no restriction on the numbers admitted. The industrial schools on the contrary, limit their numbers strictly in accord with their classroom and desk capacity.

The Higher and Middle Industrial Schools.—Schools of these types, for which we have few counterparts in America, are commonly known throughout central Europe by the name *technikum.* No collective statistics are available, but the total number in Germany is well above one hundred, with a total enrollment between 25,000 and 30,000. As a rule these schools are semi-monotechnic in type. The *maschinenbauschulen* prepare for the mechanical and electrical industries; the *baugewerkschulen* for architecture and civil construction; the *bergschulen* for the mining industry; and a rather varied group of *gewerbeschulen* for such specific industries as textiles.

leather work, paper manufacture and the like. The great majority and all of the strongest of these schools are state or municipal institutions. There are some private schools, but they are not in high favor with the public authorities and the professions, and are having a hard struggle for survival. The state schools, as a rule, are under the direction of the Ministry of Commerce and Industry. Complete separation of control tends to lessen any potential rivalries between the industrial schools and the *hochschulen,* and apparently has led to some emulation in generosity of support.

Other Polytechnic Schools.—There are two polytechnic schools which occupy a middle status between the *technika* and the *hochschulen* and which resemble more closely than any others in Germany an American engineering college—the Saxon Industrial Academy at Chemnitz, and the Polytechnic School of the small state of Anhalt at Cöthen, both giving seven-semester programs in engineering and chemistry. A school of similar character exists at Gothenburg in Sweden, the Chalmers Technical Institute, founded by an Englishman and still showing some traces of its origin. The entrance requirements are somewhat less severe than those of the universities.

Higher Institutions.—The term *hochschule* comprehends all institutions of higher learning which grant degrees and professional diplomas and is therefore best translated as "university" rather than "high school." Seven fairly coordinate types of institutions are included in this category, all of them supported by the respective States and under the direction of their ministries of Education and Worship (*Kultusministerium*).

GERMAN HOCHSCHULEN, TYPES, NUMBERS AND ENROLLMENTS * (1927)

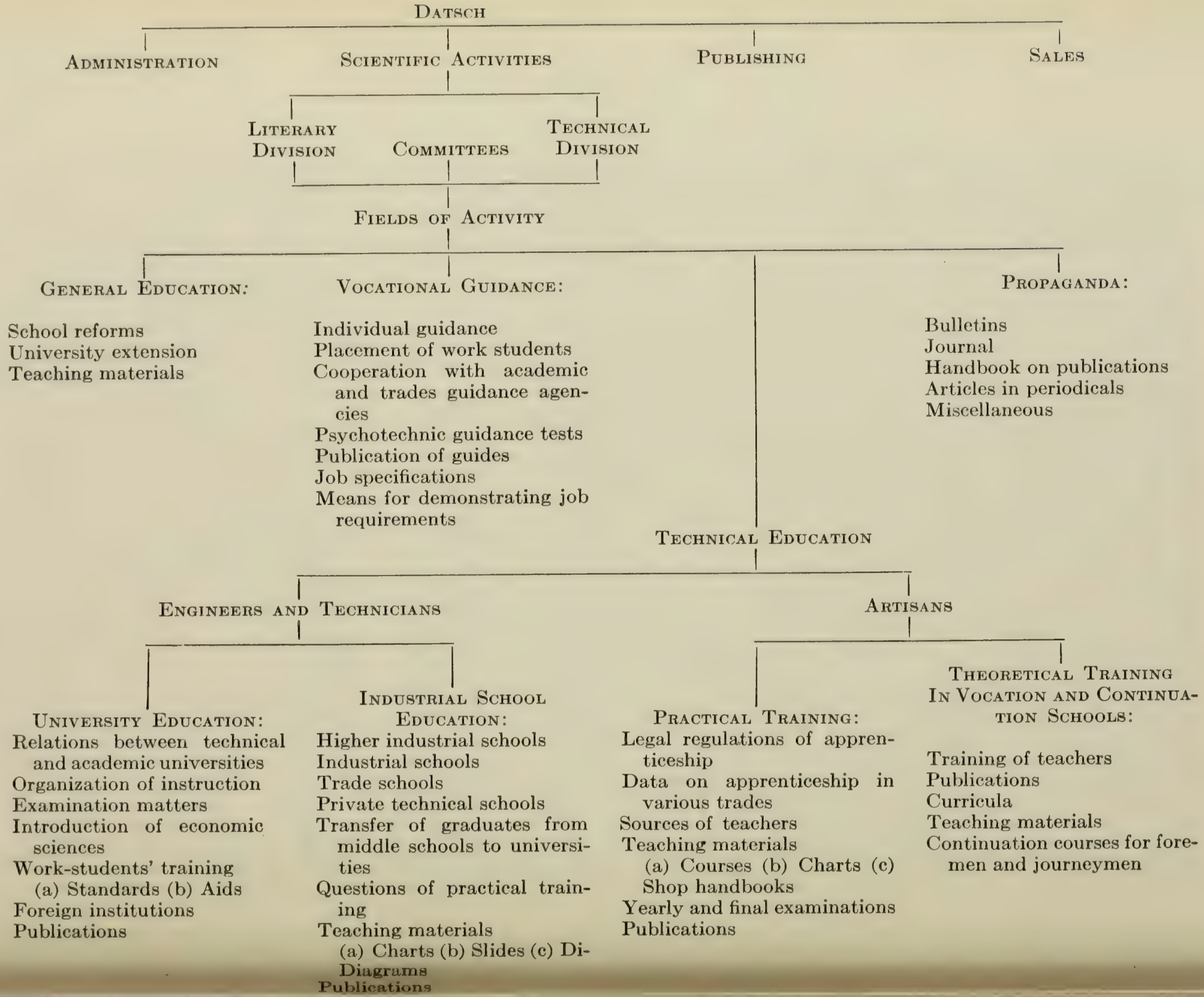
Academic Universities	23	72,189
Technical Universities	11	22,491
Higher Schools of Commerce	5	4,058
Schools of Rural Economy	4	1,702
Higher Mining Schools	2	788
Schools of Veterinarians	2	484
Schools of Forestry	3	345
	50	102,057

* Auditors and guest students not included.

The German Committee for Technical Education.—On the initiative of the *Verein Deutscher Ingenieure* there was established in 1908 a joint committee representing all the professional and industrial interests in technical education from the training of workmen to that of directing engineers. Its membership now includes forty societies and associations as well as a large number of industrial firms. Membership is gained by invitation, and funds for the Committee's work are derived from annual subscriptions and from sales of publications and teaching materials. The name of the Committee (*Deutscher Ausschus für Technische Schulwesen*) has been colloquially abbreviated to *Datsch.* The range of its activities is indicated by the accompanying function chart. The *Datsch* is administered by a general committee of six, and and by two managing directors. It is undoubtedly one of the most influential non-governmental coordinating forces in German education. Its work in vocational guidance and in the publication of teaching charts which exhibit technical standards, right and wrong construction practices, general economic facts and relationships, etc., has been especially noteworthy. The principal journal on technical education in German, *Technische Erziehung,* comes from its editorial offices. As the work of the *Datsch* benefits all industries, large and small, it appeals for subscriptions on the scale of from 3 to 10 pfennigs per year per employee.

B. THE TECHNICAL UNIVERSITIES

Organization.—Considering the large size of the technical universities and the wide range of their instruction and research, their plan of organization is strikingly simple. The teaching staff as a whole meets but rarely and the principal deliberative body is a small senate, chosen from among the regular professors. The *rektor* is a professor, elected for a term of one or two years, who represents the institution in its external relationships, presides over the senate and the ceremonial occasions of the institution and directs its academic activities in a general way. The position of *rektor* carries


DATSCH
ADMINISTRATION
SCIENTIFIC ACTIVITIES
PUBLISHING
SALES
LITERARY DIVISION
COMMITTEES
TECHNICAL DIVISION
FIELDS OF ACTIVITY
GENERAL EDUCATION:
School reforms
University extension
Teaching materials
VOCATIONAL GUIDANCE:
Individual guidance
Placement of work students
Cooperation with academic and trades guidance agencies
Psychotechnic guidance tests
Publication of guides
Job specifications
Means for demonstrating job requirements
PROPAGANDA:
Bulletins
Journal
Handbook on publications
Articles in periodicals
Miscellaneous
TECHNICAL EDUCATION
ENGINEERS AND TECHNICIANS
ARTISANS
UNIVERSITY EDUCATION:
Relations between technical and academic universities
Organization of instruction
Examination matters
Introduction of economic sciences
Work-students' training
(a) Standards (b) Aids
Foreign institutions
Publications
INDUSTRIAL SCHOOL EDUCATION:
Higher industrial schools
Industrial schools
Trade schools
Private technical schools
Transfer of graduates from middle schools to universities
Questions of practical training
Teaching materials
(a) Charts (b) Slides (c) Di-
Diagrams
Publications
PRACTICAL TRAINING:
Legal regulations of apprenticeship
Data on apprenticeship in various trades
Sources of teachers
Teaching materials
(a) Courses (b) Charts (c) Shop handbooks
Yearly and final examinations
Publications
THEORETICAL TRAINING IN VOCATION AND CONTINUATION SCHOOLS:
Training of teachers
Publications
Curricula
Teaching materials
Continuation courses for foremen and journeymen

considerable honor and responsibility, but it is accepted more in a spirit of duty than of ambition, since it entails not a little interruption of the scholarly and professional work to which a professor's career is dedicated. State responsibility for support and management, a highly stable form of organization and plan of work, and universal adherence to a common body of tradition make the direction by an elective officer practicable in Germany where it would probably prove unworkable in America. The term ''faculty'' is not applied in Germany to an entire teaching staff, but to each major or professional division (*abteilung*). The chairman of each such division is known as a dean (*dekan*). He is elected for a limited term and acts during that period as an adviser of students and as the official representative of his division in all examination matters.

Except for a few non-academic functionaries, there is scarcely any other administrative machinery—no statistical, disciplinary and personnel bureaucracies, no athletic business organizations, no housing and welfare appendages, no high-pressure promotional agencies, no faculty committees, no infirmaries for ''lame ducks,'' no daily, monthly or semester records, no recitation-quiz-term examination scheme of inspection, in fact none of the familiar alibis for intellectual non-production. The German professor has little to do but labor for the advancement of his science or profession, and that he does right diligently by teaching, directing research and giving consulting service of a high order. The German mind finds it wasteful to consume the time of professors in paternalism and thinks it more economical to let the student bear the final consequences of his work, whether good or bad.

The Teaching Staff.—The main pillars of the structure are the regular (*ordentliche*) professors. In addition there are many supplementary (*ausser-ordentliche*) professors, many of them connected with other institutions, who are engaged for limited and special duties, but whose teaching has the weight of professorial authority; also honorary professors, distinguished specialists who give occasional courses in isolated subjects. There is nothing in the Germany system comparable to the associate and assistant professorship, for the simple reason that one does not advance to a regular professorship by promotion, but gains his appointment from the State only after distinguished achievement. Much of the teaching of secondary importance is done by private tutors (*privat-dozenten*) who are authorized to offer courses and practical exercises and to receive compensation from the course fees. Many men win their way to professorial appointments in non-professional branches through this form of service as a supplement to their researches. The numerous assistants are recent graduates doing research as doctor-candidates and earning support by part-time teaching in the practical exercises which supplement the professorial courses. It is easy to secure the best men for this service as the compensation (about 200 marks per month) is as attractive as the scale for beginners in industry and the doctorate commands a fast-rising premium in all professional circles. The appointment is strictly temporary, and can not be extended beyond five years.

Professors, Their Status and Functions.—The regular professors are high officers of State, appointed by the Ministry from nominations submitted by the Senate, paid from the public treasury and unremovable except for the gravest offence. Their position is one of great independence, free from all disciplinary control by the institution as such. In principle, their duty is simple—to devote their energies to the advancement of their science or art for the common good. They are free to teach what and as they choose. They may divide their time between teaching, research and consulting service much as they choose, provided that they keep their obligations scrupulously after they have assumed them, but there is an intangible code which forbids them to follow after "pot-boilers."

All in all, the regular professors are among the best paid and most highly honored state functionaries. There is a basic salary scale, beginning at about 7,500 marks per year, and a schedule of seven biennial promotions. Actually, the

State makes an individual contract with each appointee, crediting his previous experience as so many promotions and often adding a permanent differential for men of special distinction. Professors also receive part of the fees paid by students for their courses and this sum varies widely, being quite large where the courses are obligatory and quite small where they deal with limited specialties. Supplementary earnings from consulting service and patent royalties vary greatly. The total from all professional sources ranges from 10,000 to 40,000 marks per year ($2,500 to $10,000) and there are said to be few salaried officials in either government or industry who exceed the latter figure. The median for professors is estimated at 15,000 to 16,000 marks, while that for an able diploma engineer at the height of his career is said to be between 10,000 and 12,000 marks.

Appointment to a professorship commonly comes in mature life, after fifteen to twenty years of active experience. It is the universal testimony that a highly placed engineer or technical director in industry will invariably accept a call to a professorship in a spirit of public duty. The German instinct of working through common channels for the advancement of technical science, rather than through competitive efforts, stands out very strongly. Furthermore, the professorship commands the highest prestige and influence in all professional and industrial circles. The problem of commanding the services of the most creative minds is simplified by the fact that there are but thirteen higher technical institutions with probably not more than 500 regular professorships in all, and not more than 300 of these in distinctly technical branches.

The Unit of Teaching Organization.—Departmental teaching, shared by a group of professors and subordinates in common, is practically unknown in Germany. Each professor as an individual, with his assistants and the necessary physical plant, constitutes a distinct teaching unit. The larger units are known as "institutes." For an example, we may picture the setting in which a leading professor of heat engines does his work. His institute is a commodious building with well fitted offices, an ample professional library, drafting rooms, an ampitheatre for lectures, a general laboratory and a group of special laboratories—in short a complete working establishment in which the professor is virtually a chief engineer, his assistants are supervising engineers, and the students are engineering novices. The professor gives perhaps two courses of formal lectures each semester, assigns the project work done by upper class students and gives some general supervision to the laboratory instruction conducted by his assistants. He also has a laboratory full of research problems, not shut up in private rooms, but out in the open where undergraduates do their work. Many of these researches are being prosecuted by *doktoranten,* but the professor also has on his hands expert problems as a consultant, for which he may engage private assistants, and on which he and they work on the school premises and not in a professional office downtown. The atmosphere of the place is decidedly that of real engineering work in progress and not that of a glorified school house. It is, of course, impossible to estimate the teaching loads of professors of this type. They have few fixed appointments and teach but few hours per week in a formal sense, but they direct a volume of work limited only by their creative ability and their power to draw disciples about them.

Forms of Teaching.—While the lecture has a prominent place in the formal processes and programs, the essence of the system is closely akin to the atelier method of the fine arts. The student is taught his fundamental science and technique didactically by lectures and graded exercises; he then begins to produce original work under the observation and criticism of a master and in an atmosphere of creative effort. When he reaches the point where his execution is competent and he is able to pass a valid judgment on his own work, he is turned loose to go it alone. It is the project work of the two final years rather than the lectures or the detailed exercises in drafting room and laboratory which give the characteristic tone to the process and in large measure determine its final success at the diploma examination.

The lectures are, as a rule, formal in character but copiously illustrated by experiments, projections, models and charts. The collections of teaching materials of this character are often extraordinary in their completeness and ingenuity. Lecturers usually develop the theory of their subjects but once, and use mathematical and graphical forms of analysis with a free hand. The exercises which supplement the lecture courses are organized with varying degrees of efficiency. In non-experimental subjects the groups are sometimes as large as 800, and while the assistants are numerous it is not common practice to divide the group into sections assigned to individuals for supervision. Lecture courses are of widely varying excellence, depending upon the attainments and expository ability of the professor. The pace of advance is fairly rapid, the scientific tone high, and there is little concession to the slow or mediocre student. Students, as a rule, are industrious note-takers and write extended memoirs on their exercises and projects. Textbooks are unknown. Students buy for their libraries the best professional treatises they can afford and read rather widely on their own initiative. The library collections are very complete, but library service is relatively meager for lack of funds.

The laboratory exercises in physics and chemistry are not significantly different from our own. In the technical branches, however, the laboratory exercises are both fewer in number and less individual. Laboratories for student instruction were introduced at a relatively late period in the development of the schools and many of them were actually extensions of private laboratories which professors had built up for personal research. There is relatively less apparatus than in a typical American laboratory and much of it is in fairly large units installed with a primary view to research possibilities. One gains the impression that research still has the right of way over routine teaching. Laboratory squads are fairly large, often as many as ten to fifteen men. The student gets comparatively little individual manipulative experience, but there is always some rotation in the posts of observation. The tests are commonly quite comprehensive and the student is expected to submit his results to an extended analysis. The collection of memoirs of a year's work in one laboratory course is a fair approximation to a personally written treatise of the subject. The work in the laboratories of electrotechnics is more nearly individual. Smaller equipment is available, there is some duplication, and squads of five and less are the general rule.

Projects.—The student faces the real test of his progress in the engineering projects which occupy a large part of his time during the last two years of the course. The projects are design problems of graded difficulty and complexity. The student is expected to perform original and independent work, setting forth his entire process in orderly memoirs and well rendered drawings. He is free to do this work when and where he chooses, but most students find it convenient to work on the school premises, under the advice and criticism of the ever-present assistants and with occasional counsel from the professor in charge. The emphasis given to projects in the French and German systems is fairly equal; the French student, however, is thrown absolutely on his own, since the professor is absent with his practice and there are no assistants. A German student will usually perform projects under six or eight different professors, each a specialist in some division of his major subject. A student of civil engineering, for example, may submit a portfolio at his final examination with projects on a piece of railroad location, a small water supply or sewage disposal system, a masonry or concrete arch bridge, a steel framed structure, a foundation or underground structure, a water-power development or a canalization project, and one project of much larger scale in fairly complete detail with working drawings, estimates and extended memoirs on which he has spent three full months of independent work as his thesis (*diplom-arbeit*). While design projects are not insisted upon in all cases, it is not easy to provide facilities for extended experimental projects in hard-worked laboratories. These privileges are likely to be reserved for the doctor candidates.

Results of Project Teaching.—Project teaching in the form suggested above gives the graduate a strong bias toward design activity. He usually begins work in an office rather than the shop or field and sticks to the purely technical side of the profession for life. The professors everywhere insist that it is possible to train competent designers in a school provided the student has fulfilled the requirement of a year's practical experience (six months for civil engineers) before the upper years. The designer is trained more in the spirit of an artist than that of an industrial economist; he aims at a theoretically perfect machine or structure rather than one good enough for its purpose; he works materials close to the permissible limits; but he succeeds best with products which are to be individually built, with unlimited skilled labor, rather than standard lines to be manufactured in series or assembled from standard parts with a minimum of labor. This type of design engineer appears to have fitted into the old economic system reasonably well, but with the present immense pressure toward quantity production the old emphasis on individual design is yielding ground to a more practical training with a bias toward standardization and economic selection. The force of tradition is strong and the influence of the older professors dominant. Reform comes slowly as new men appear, but the present norm seems good for many years to come. Teaching of this character demands professors of a specialized type. At Charlottenburg, for example, there are five distinct divisions of teaching in the field of heat engines, a condition which is explained as due to pressure from the industries. The formula for keeping Germany from being outdistanced in any specialty, it seems, is to get the ablest man obtainable to profess it.

Research Activity.—Research and teaching can not be separated in the higher technical education of all central Europe. Schools and professors are there to advance the technical sciences and arts and are regarded as the first line of national defense and of advance in industrial competition. Everywhere are evidences of a wise policy of concentrating the limited resources around the most productive man rather than scattering them ineffectually among many institutions. Rivalry between institutions and individuals doubtless exists, but has been subordinated to the common interest in a period of economic crisis. It appears that America thinks in terms of competition between firms and institutions, central Europe in terms of competition between nations; hence our extreme decentralization of research and their solidarity.

Notable examples of research institutes which have grown up around some individual genius are Professor Rhebock's laboratory of hydraulic construction at Karlsruhe, Professor Knoblauch's institute of heat technics at Munich, Professor Glocker's institute of X-ray technics at Stuttgart, Professor Petersen's high voltage laboratory and Professor Jonas' cellulose institute at Darmstadt, Professor Josse's laboratory of heat engines (originally created by Professor Riedler) and Professor Schlesinger's laboratory of machine tools at Berlin, Professor Schwerd's laboratory for piercing and drawing operations at Hannover, Professor Nägel's institute of piston engines and Professor Sachsenberg's institute of psychotechnics at Dresden, the incomparable institute for metallurgical research at Aaschen, Professor Rôs' great materials testing institute at Zurich, and Professor Lindmark's center for boiler and furnace research at Stockholm. While precise figures are unknown doctor candidates are probably more numerous in Germany than candidates for master's degrees in our engineering colleges, and the volume of research production is correspondingly great. The industries and the *Verein Deutscher Ingenieure* are very active in fostering research, both by generous loans of equipment and by grants of funds. Some apprehension has been caused in the technical universities, however, by a growing tendency among the industries to set up private research departments on American lines.

Summary of Formal Requirements.—(1) *Admission,* for matriculated students, the maturity certificate of any Germany secondary school, or foreign credentials judged equivalent. Auditors (*hörere*) are admitted to courses provided they have completed six years of secondary education, have passed the *obersecunda* examination and furnish evidence of experience which will enable them to follow the work with profit. Auditors are ineligible for the diploma, but may obtain a certificate of courses and exercises completed. Guest auditors, that is students of other institutions and men employed in practice, may be admitted to single lecture courses.

(2) *Curricula,* not less than eight semesters of matriculated study. There is no obligatory plan of studies, but the work normally required to qualify the student for the prescribed examinations is arranged as a *studienplan* and the exercises are scheduled accordingly, so as to avoid conflicts. In addition to the courses, exercises and projects preparatory to the examinations, a thesis (*diplom-arbeit*) is required, consisting of a project on which the student must work independently and without interruption for three months. The academic program as a whole is virtually equivalent to nine semesters.

(3) *Qualifying Experience.* In order to be admitted to the diploma examination the student must present formal evidence of having completed a period of practical experience. The prescribed period for mechanical and electrical engineers and for metallurgists is one year; that for civil engineers and architects is six months.

(4) *Diploma Examination* in two stages, a *vor-prüfung* which covers the general scientific and elementary technical subjects after four semesters and a *haupt-prüfung* on completion of the professional courses, exercises, projects and thesis.

(5) For the *Doctorate,* a scientific dissertation of high rank and an oral general examination, preceded by the degree of *diplom-ingenieur.*

The Diploma Examination.—The formal requirements are largely comprehended in two general examinations, the *vor-prüfung* which normally comes at the end of the fourth semester and the *haupt-prüfung* at the end of the course. The regulations are laid down by the Ministry and vary in details from State to State, but conform in their main features to a common norm. A distinctive feature of the system is that of making the student entirely responsible for submitting evidences that all the requirements have been fulfilled. The professors keep only such private records as they choose and make no reports on term work. Each student has a registration book in which he inscribes the courses and exercises pursued, and has each item visaed by the professor in charge at the beginning and end of each semester. All exercises performed must also be visaed by an authorized assistant and major projects by the professors. These are carefully preserved for inspection at the diploma-examination.

Each section of the examination consists in part of an inspection of evidences of matriculation and of registration in courses and exercises, of formal certificates covering the required practical experience, and of the practical exercises prescribed, and in part of a series of oral examinations. The examining committee may, at its option, set written examinations as well. In short, the student is judged by his accomplishments more largely than by his essay-writing ability or an inventory of his detailed knowledge. The examination is in reality not an academic test, but a State examination for professional certification. This principle is expressly stated in the diploma examination ordinances of the Prussian *Kultusministerium:*

> "By passing the diploma examination the applicant shall give proof that during the course of his studies at the technical university he has acquired a sufficient foundation for independent activity in his profession, guided by scientific or artistic points of view."

Each faculty (*abteilung*) appoints its own examining committee under the chairmanship of the dean, with the right to include examiners from other faculties for particular subjects. If the preliminary examination has been passed at some other institution, it is accepted in principle, but the applicant may be required to make up essential differences. The faculty has the privilege in exceptional cases of crediting time spent in shops and offices for special training up to half its total duration in place of courses and exercises in the university; the student, however, must be examined on this work, and the total period of internal studies must not be less than six semesters. The faculty may permit the applicant to take either of his examinations in two sections, separated from each other by not less than one or more than three semesters. The results of the exercises, the thesis and the several branches of the oral examinations are graded separately as "very good," "good," "fairly good," "sufficient" or "insufficient." These are consolidated into a total grade as follows, "passed with distinction," "passed very well," "well passed," "passed," or "not passed." The examination is recorded as "not passed" if a grade of "insufficient" is given in any of the prescribed branches. A failure in an optional branch, however, may be compensated by passing in an additional option of equal weight, beyond the usual requirements. In cases of partial failure the examination in the individual branch may be repeated only once. It is said that ten to fifteen per cent of the candidates are held up.

The mental examinations occupy one hour in each subject and are taken by the students in groups of four. Questions are put orally, but the student may sketch or explain by diagrams, write out equations, etc. The final examinations are made an event; the student presents himself in formal dress, and the punctilio of the occasion is meticulously observed.

Examples of Examination Requirements.—The following schedules of examination subjects are taken from the ordinances of the State of Prussia and apply equally to all the technically universities in that area:

DIPLOMA EXAMINATION FOR CIVIL, ELECTRICAL AND MECHANICAL ENGINEERS

Preliminary Examination

	Inspection of Exercises			Oral Examinations		
	Civ.	Elec.	Mech.	Civ.	Elec.	Mech.
Higher Mathematics	x	x	x	x	x	x
Descriptive Geometry	x	x	x	x	x	x
Mechanics and Graphic Statics	x	x	x	x	x	x
General Physics and Chemistry				x	x	x
Physics		x	x			
Mineralogy and Geology				x		
Structural Drawing	x					
Machine Elements and Drawing	x	x	x			
Free-hand and Architectural Drawing	x					
Surveying	x			x		
Materials and Theory of Construction				x		
Testing of Materials	x					
Materials and Ferrous Metallurgy		x	x		x	x
Principles of Mechanism				x	x	x
Principles of Economics				x	x	x
Elementary Thermodynamics					x	x
Mechanical Laboratory		x	x			
Elementary Electrotechnics					x	x
Electrotechnical Laboratory		x	x			

FINAL EXAMINATION, CIVIL ENGINEERS

Inspection of Exercises and Projects

All exercises and projects must be submitted in subjects in which the candidate is examined.

Oral Examinations

I. Obligatory Branches:

1. Theory of Structures.
2. Civil Engineering Design (Bridges, framed structures and industrial structures in steel, reinforced concrete, masonry and wood).
3. Hydraulic Construction and Operation.
4. Railways (Construction, operation and management; signals and safety appliances; tunneling).
5. Highways and City Planning (Roads, streets, and underground construction).
6. Mechanical and Electrical Engineering.

II. Optional Branches:

In place of two of the required branches with the exception of 1 and 2 two alternatives may be chosen from any department of instruction, subject to the approval of the Faculty.

III. Special Examination:

A special examination to test the candidate's knowledge more profoundly, is given in one of the major branches of civil engineering, usually in the branch from which the thesis was chosen.

FINAL EXAMINATION, ELECTRICAL ENGINEERS

Inspection of Exercises and Projects

I. Obligatory Branches:

1. Project of a dynamo machine or a piece of communication apparatus.
2. Project of an electrical installation.
3. Exercises from the laboratories of electrotechnics and communications.
4. Design drawings of a power machine and exercises from the mechanical engineering laboratory, or design drawings of a machine tool and exercises from the experiment station for machine tools.
5. Calculations and drawings of a transformer or a dynamo machine.

II. Optional Branches:

1. A special study in electrical engineering or a related field, such as an extended theoretical study, or an experimental study in the laboratory, in industry, or in operation.

Oral Examinations

I. Obligatory Branches:

1. Theoretical Electrotechnics.
2. Electrical Installations (power or communications).
3. Design of Electrical Machinery or Apparatus and Instruments for Measurement or Communication.
4. Heat Power Engineering.
5. Factory Organization and Management.

II. Optional Branches:

At least three branches, from any department of instruction, subject to the approval of the Faculty, which may include a more advanced study of some subject already covered in the preliminary or final examination.

FINAL EXAMINATION, MECHANICAL ENGINEERS

Inspection of Exercises and Projects

I. Obligatory Branches:

1. Exercises in the Mechanical Laboratory.
2. Exercises in Electrotechnical Laboratory.

3 and 4. Two design projects, at least one from the field of Prime Movers.

5. Design Drawings in Framed and Underground Structures
6. At least one Project in the Field of Mechanical Technology or Industrial Management.

II. Optional Branches:

1. At least one additional project selected from a related field of design, Industrial Management or Science or from the Field of Applied Mathematics.

Oral Examinations

I. Obligatory Branches:

1. Heat Power Engineering.
2. Design of Power Machinery.
3. Industrial Machinery including Hoisting and Conveying Equipment.
4. Electrotechnics.
5. Factory Organization and Management.

II. Optional Branches:

At least three branches, from any department of instruction, subject to the approval of the Faculty, which may include a more advanced study of some subject already covered in the preliminary or final examination.

Curricula.—The study plans of the technical universities vary considerably in detail, but conform sufficiently to a common pattern so that a student may migrate from one to another without serious loss of time or standing. Specialization in the several professional divisions begins in a small degree at the outset and increases from year to year. The two largest divisions, mechanical and electrical engineering, differ but little before the third year. The faculty of general science (*allgemeine abteilung*) gives the general introductory courses for all curricula and offers, in addition, complete programs of training for teachers of mathematics, and of physical and natural science. The chemical curriculum is more technical in character than that given in the academic universities, but includes few distinctly engineering subjects. Architecture is taught with a greater emphasis on its aesthetic than its technical aspects. The programs in civil, mechanical and electrical engineering frequently provide for subordinate group options. All normal study plans include a wider range of studies than that covered by the obligatory branches of the diploma examination. Since the late War, a strong effort has been made to increase the pursuit of economic and social sciences by technical students.

The programs of work run from thirty hours per week upward and divide roughly into equal periods of lectures and exercises. The proportion of the total time given to strictly professional instruction is conspicuously large. The student enters with some knowledge of calculus and completes this subject in his first year. He begins his technical mechanics at the outset and is ready to begin his study of applications in the second year. The total time given to engineering applications, as distinct from the general and technical sciences, is but little less than two full years, or practically three times that given by the American undergraduate to studies of this character.

Examples of Normal Study Plans.—As the curricula are elaborate and fairly complex, limitations of space will allow but two examples to be given in detail, the programs in Mechanical and Electrical Engineering at Karlsruhe:

CURRICULA IN MECHANICAL AND ELECTRICAL ENGINEERING, TECHNISCHE HOCHSCHULE, KARLSRUHE

First Year Common to Both

	Semester			
	Winter		Summer	
	Hours per Week			
	Lect.	Exer.	Lect.	Exer.
Higher Mathematics	5	2	4	2
Descriptive Geometry	4	4	1	1
Physics	2		2	
Technical Mechanics and Exercises	4		4	
Inorganic Chemistry			5	
Properties and Working of Materials	2		2	
Machine Drawing	1	5	1	3
Principles of Machines	3		3	
Political Economy	2		2	
Recommended:				
Applied Mathematics	2	1		

Mechanical and Electrical Engineering, Second Year

	Curriculum.		Semester			
			Winter		Summer	
			Hours per Week			
			Lect.	Exer.	Lect.	Exer.
Higher Mathematics III	M.	E.	3	2		
Physics II	M.	E.	2		2	
Technical Mechanics III with Exercises	M.	E.	4		4	
Organic Chemistry	M.	E.	1			
Technical Thermodynamics I	M.	E.	3	2		
Elements of Machines	M.		4	8	3	6
Elements of Machines		E.	4	6	3	6
Properties and Working of Materials	M.		2	2		
Properties and Working of Materials		E.	2			
Laboratory of Mechanical Technology	M.					3
Laboratory of Mechanical Technology		E.				1
Lifting Machinery	M.				4	
Crank Shafts and Fly-Wheels	M.				2	3
Elementary Electrotechnics	M.		2		2	
Elementary Electrotechnics		E.	3		2	
Electrotechnical Seminar	M.		2		2	
Mechanical Measurements I	M.	E.			1	
Mechanical Laboratory I	M.	E.				3
Electrical Communications		E.			2	
Elementary Illumination		E.			2	1
Elements of Electro-chemistry		E.			4	
Physical Laboratory I		E.		6		
Civil and Commercial Law	M.	E.	2		2	
Recommended:						
Applied Mathematics A	M.	E.	2	1		
Physical Laboratory	M.					3

Mechanical Engineering, Third Year

Group Options Indicated by Numbers:

1. General Machine Design
2. Heat Power
3. Lifting and Pumping Machinery
4. Production and Management
5. Hydraulic Power and Machinery
6. Theoretical and Experimental Option
7. Option for Technical Teachers

	Option	Semester			
		Winter		Summer	
		Hours per Week			
		Lect.	Exer.	Lect.	Exer.
Lifting Machines I Exercises	1 2 3 4 5 6 7		6		
Lifting Machines II	1 2 3 4 5	4			6
Heat Engines and Boilers I	1 2 3 4 5 6 7	4	3		
Heat Engines II	1 2 4 6 7			3	3
Heat Engines III	1 2 4	2			
Kinematics	1 2 3 4 5 6 7			2	2
Technical Thermodynamics II	1 2 6	2	1	2	
Water Turbines and Rotary Pumps I	1 2 3 5 6 7			4	1
Technical Mechanics (Advanced)	1 2 3 5 6	3			
Governors	1 2 5 6			2	
Principles of Industrial Organization	1 3 4	2			
Mechanical Laboratory I	1 2 3 4 5 6 7			1	3
Selected Topics on Mech. Eng. in English		2		2	
Electrical Engineering	1 2 3 6	4			
Structural Engineering	3 4 5 7			2	2
Social Hygiene	4 7	2		2	
Industrial Heating	2 4 6	2			
Water Power Plants	5			2	
Railroads		4			
Industrial Personnel		2	2	2	2

Mechanical Engineering, Fourth Year

	Option	Semester			
		Winter		Summer	
		Hours per Week			
		Lect.	Exer.	Lect.	Exer.
Loading and Transport Equipment	3 4			2	3
Projects on Steam Engines	1 2 4 7		6		
Heat Power Machinery III	1 2 4	2			
Machine Tools and Projects	1 2 4 7	2		2	7
Mining and Metallurgy	1 3 4	2		1	
Testing of Materials of Construction	4 6				2
Principles of Pre-determination	1 3 4			2	
Heating and Lighting I and II	1 2 4 6	2		2	2
Refrigeration I and II	1 2 4 6	2	2	2	2
Advanced Thermodynamics	1 2 6			2	
Water Turbines and Rotary Pumps I	1 3 5		4		
Fluid Dynamics	5	3			
Water Turbines and Rotary Pumps II	5	2			4
Laboratory of Hydraulic Machinery	5				4
Advanced Technical Mechanics	1 2 3 5 6	3			
Governors	1 2 5 6			2	
Locomotive Design	1 2 7			4	
Mechanical Laboratory III	2 6				3
Automotive Engineering				3	
Principles of Aeronautics		3	1		
Diesel Engines		2			
Thermodynamics Seminar			2		
Recommended:					
Applied Mathematics B		2	1		
Theoretical Physics	6	2		2	
Surveying I	3 5	4	2		
Electric Transmission and Distribution	5	2		2	
Electrotechnical Laboratory	1 2 3 6		3		
Steel Structures	3	2	3		
Exercises in Hydraulic Construction	5		6		
Laboratory of Hydraulic Construction	5		4		
Railways		4			
Railway Operation		1			
Railway Terminals		2			
Railway Signals and Safety Appliances		1			
Economics Seminar	4		2		
Industrial Welfare		2			
Social Legislation	4 7	2	2		
Chemical Technology	1 2	3			
Technical Analysis	2			1	3

Electrical Engineering, Third Year

Group Options Indicated by Number:

1. Heavy Currents
2. Light Currents
3. Illumination

	Option	Semester			
		Winter		Summer	
		Hours per Week			
		Lect.	Exer.	Lect.	Exer.
Electrotechnics, Heavy Currents	1 2 3	4			
Electrical Machine Construction	1 2	1		4	
Exercises in Machine and Apparatus Design	1 2				6
Theoretical Electricity I and II	1 2 3	3		4	
Electrotechnical Laboratory	1		6		3
Electrotechnical Laboratory	2 3		6		6
Mechanical Laboratory	1		3		
Heat Power Machinery	1	4	3		
Heat Power Machinery	3	4			
Lifting Machinery	1			4	3
Hydraulic Motors	1			4	1
Technique of Communication	2	2	1		
Light Current Apparatus and Instruments	2			3	2
High Frequency Technique	2	1		2	2
Technique of Light	3	2	2		
Illumination, Science and Art	3			3	2
Laboratory of Light Technique	3		3		6
Physics and Physiology of Photometry	3	2			
Physiological Optics and Color	3	2			
Geometrical Optics	3			2	
Industrial Heating	3	2			
Chemistry of Water and Gas	3			2	
Interior Architecture	3			2	
Recommended:					
Theory of Alternating Currents	1 2 3	2	1	2	1
Theory of Transient Disturbances	1	4			
Induction Machines	1			3	
Regulators	1			2	
Advanced Mechanics	1	3			
Heat Power Machinery II	1			3	
Water Power Plants	1 3			2	
Machine Tools	1 2	2	2	2	2
Electrical Machine Construction II	3			4	6
Physical Chemistry	3	5			
Photochemistry	3	1			
Photography	3		2		2
Gas Apparatus and Heating	3	2			
Fuel Economy Seminar	3		3		
Industrial Personnel	1 2 3	2	2	2	2

Electrical Engineering, Fourth Year

	Option	Semester			
		Winter		Summer	
		Hours per Week			
		Lect.	Exer.	Lect.	Exer.
Electrical Machine Construction	1 2			4	
Exercises in Electrical Machine Design	1 2		6		6
Power Plants and High Potentials Technique	1	2		2	
Power Plants and High Potentials Technique	2 3	2	3	2	
Motor Drive and Railways	1	2	3	2	3
Electrotechnical Laboratory II	1 2 3		6		
Electrotechnical Laboratory III	1				8
Electrotechnical Laboratory III	2		6		8
Hydraulic Motors	1		4		
Communication Technique II	2	3	1		
Technical Optics	3	2			
Physical Laboratory	3		3		
Gas and Coke Industry	3			1	
Special Items in Technical Analysis	3			1	3
Gas Distribution	3			1	
Internal Combustion Motors	3	2			
Laboratory of Illumination	3		6		6
Colloquium on Illumination	3		2		2
Recommended:					
Illumination Technique	1	2	2	3	2
Illumination Laboratory	1		3		
Fluid Dynamics	1	3			
Diesel Motors	1	3			
Regulators	1			2	
Advanced Mechanics	1	3			
Locomotives	1			4	
Structures	1			2	
High Frequency Technique	1	1		2	2
Automotive Engineering	1			3	
Electrical Economics	1			1	
Railways	1	4			
Railway Operation	1	1			
Selected Items in Experimental Physics	3	2			
Electrical Machine Construction	3			4	6
Technical Analysis for Gas Engineers	3	1	2	1	2
Management of Fuel Industries	3				3
Exercises in the Gas Institute	3		2		2

Costs and Fees.—The average expense of instruction per student per year in the technical universities is reliably estimated at about $375 to $400. Students pay itemized fees according to the courses taken. The semester fee for each hour per week of lectures and class exercises is usually 3 or 3.5 marks. A minimum total tuition fee is sometimes set as, for example, at Karlsruhe, where it is 90 marks per semester. Additional fees are charged for laboratory courses, ranging from 5 to 50 marks per semester, according to the time worked. Materials used in laboratories are covered by additional charges. The fees for diploma examinations amount to from 75 to 100 marks. Special fees are charged for matriculation, the use of the library and group insurance against illness or accident. The total of all fees is normally less than $100 per annum.

Enrollments.—The enrollments in the several institutions, and the totals for the several faculties of the technical universities, for the summer semester of 1927 were as follows:

ENROLLMENTS OF MATRICULATED STUDENTS, SUMMER SEMESTER, 1927

Technical Universities:	
Aachen	984
Berlin	4,358
Braunschweig	945
Breslau	787
Danzig	1,515
Darmstadt	2,346
Dresden	2,341
Hannover	1,807
Karlsruhe	1,239
Munich	4,398
Stuttgart	1,771
Mining Universities:	
Clausthal	421
Freiberg	367
Total	23,280

Faculties of Technical Universities:	
General Science	2,907
Architecture	1,749
Civil Engineering	2,413
Mechanical Engineering	7,314
Electrical Engineering	4,513
Naval Architecture	314
Aeronautics	116
Mining	474
Ferrous Metallurgy	464
General Metallurgy	71
Chemistry	2,020
Pharmacy	136
Total for Mineral Technology (All Institutions)	1,797

Discipline and Eliminations.—Under the principle of *lernfreiheit* the student is free to attend or to absent himself as he pleases. He is not held to a fixed curriculum, but only to the completion of required preliminaries for a professional examination. Official discipline is thus reduced to a minimum, and the student is assumed to be self-sufficient. Under the easier economic conditions before the late War, there was considerable abuse of freedom during the first year and many cases of failure or delay resulted. This condition has since corrected itself. The statistics of the diploma examinations show little or no abuse of freedom.

RATIO OF DIPLOMAS AWARDED TO ENROLLMENTS

Prussian Technical Universities, 1924–25

Faculty	Diplomas	Enrollment	Ratio	Ratio × 4½
Architecture	71	386	.183	.825
Civil Engineering	121	641	.187	.845
Mechanical Engineering	421	2,772	.152	.685
Electrotechnics	173	1,667	.103	.465
Naval Architecture	31	179	.172	.775
Mining	110	638	.172	.775
Metallurgy	74	536	.138	.620
Chemistry	127	761	.167	.750
Total	1,128	7,580	.149	.669

The ratio multiplied by 4½, or the total years of enrollment, gives an approximate indication of the ratios of completion in the several courses of study.

Placement in Industry.—The preliminary experience required before the diploma-examination is ordinarily secured by taking six continuous months between graduation from the secondary school and entrance to the university and two three-months periods during subsequent vacations. The secondary courses end in April and the winter semester begins in November in order to facilitate this practice. The student must make his own arrangement with an employing concern, and ordinarily pays a premium of from 200 to 500 marks for the privileges of a *praktikant* or work student. In some cases there is an opportunity to earn the fee back. Employers generally recognize their obligation to accept *praktikanten,* thanks to the active propaganda of the *Datsch.*

Placement after graduation is not systematically organized. One leading authority describes the process as a lottery. The more progressive concerns, such as the A. E. G. (German General Electric Company), are beginning to follow American recruitment practices. The A. E. G. gives graduate training courses of two years in six divisions: (1) Production engineering on heavy machinery, (2) production engineering on light apparatus and instruments, (3) testing engineering, (4) laboratory development of apparatus and instruments, (5) installation engineering, and (6) sales engineering. Diploma-engineers are usually placed at initial salaries which cover the bare cost of subsistence (150 to 200 marks per month). Apparently they find places enough, but the oversupply shows itself in the unemployment of engineers in middle and later life, which is said to constitute something of a crisis.

Progressive Movements.—There are signs that the historic breach between the academic and the technical universities may be healing. It has been proposed to establish new universities of a general character at Münster and Kiel with faculties of technical sciences, also to expand the present technical university at Dresden into one of comprehensive character. There is a growing body of opinion that these moves would benefit higher technical education by bringing it into closer union with the political, economic and human sciences. The present effort to increase facilities in these branches in the technical universities is being hindered by jealousies and vested interests which grow out of the traditional separation of academic, technical and commercial education. Some leading authorities are urging a union of the two latter types in "universities for technics and business." The technical university at Munich has absorbed the *handelshochschule* and may be a model for similar combinations.

Meanwhile the teaching of management subjects under engineering auspices is making rapid headway on every hand. Problems of industrial personnel are being approached through scientific research in psycho-technical institutes in the technical universities, and with an intimate union of engineering and psychology, rather than as a personal art to be expounded by practical executives. Two aspects as especially stressed, vocational selection of workers and the standardization of working conditions and loads for maximum production. The technics of tools and mechanical production are also objects of the most active research. The technical universities are leading the movement.

There is a strong movement to create closer contact between students and teachers. The lecture and project system bids fair to endure, but a greater degree of practical teaching in smaller sections is being sought. The authorities are making an effort to reduce the overloading of schedules and to restrict the instruction more closely to the scientific and economic bases. The Prussian Ministry, for example, has limited all programs to a maximum of 35 hours per week and has recommended a reduction to 30. The problem of selective admission is assuming serious dimensions; there is a desire to adhere to the German tradition of an open door on the one hand, and on the other to set more selective qualifying standards in the course itself.

The human side of higher education is not being neglected. An all-university student self-help association now provides non-interest bearing loans, to be repaid after graduation. An increasing number of students earn part of their expenses, but it is considered poor economy to sacrifice the efficiency of one's studies to this end. Sport is being actively encouraged, but more largely on English than American lines. Student common rooms have been created and low-priced refectories set up at many higher institutions. The somewhat stilted traditions of student life which worked so strongly for the old caste system and against the development of independent personalities have been much modified. The corporations, however, still rule their members with a strict discipline and are commonly regarded as inner shrines of the old nationalistic spirit. The German student, while more independent and democratic in spirit, is still far from resembling the easy-going, self-confident American campus idol. He remains, as a type, professionally minded. The training in business enterprise, the experience of personal leadership, the spirit of team work, and the self-testing processes which result from our multifarious campus activities and do so much to ease the transition of the American student into business life, are still peculiarly American. College life is a juvenile world in America; it is an adult experience in Germany; and Germans who know us best bid us not .to change too far or too fast.

C. THE HIGHER AND MIDDLE INDUSTRIAL SCHOOLS

Functions and Types.—As the German industrial system holds little or no place for the untrained man the importance of a graded system of technical education which covers the entire range from the artisan to the research scientist is universally recognized. Limited places and scanty means forbid any sentimentalism about training every boy to go to the top. Everyone accepts the principle of selection in technical education, based on a combination of personal aptitude, previous education and the test of actual experience. Unbroken schooling is little favored as a mode of preparation, except for research scientists. The higher and middle industrial schools cater to young men who have spent from two to four years in practice and through this trial have shaped their purposes to quite definite ends. This break, as a rule, makes them less bookminded and more disposed to the practical than the highly intellectual pursuits. Furthermore, the strong scientific emphasis in the training of the technical universities needs a counterpoise of more practical character. German industry would probably find it hard to manage without the more practically trained *techniker* as an intermediary between the *diplom-ingenieur* and the working forces. There are vast numbers of small industries in all central Europe into which the highly professional *diplom-ingenieur* scarcely fits at all and which need a more adaptable type of technical direction.

The technical universities and the intermediate schools organize their work on quite different lines. The entire scheme of university teaching is professional. Each professor is king of his castle and teaches his subject with a large measure of independence. Students come and go as they please, piecing together the units of instruction and performance needed to pass their several qualifying professional examinations. The intermediate technical schools, in contrast, organize their teaching on industrial lines—mechanical, electrical, structural, mining, metallurgical, shipbuilding, textiles, and the like; their regime is but little less disciplinary than that of industry itself; and their teaching is built up in closely coordinated programs.

The most numerous types are the *maschinenbauschulen* devoted to the electrical and mechanical industries, the *baugewerkschulen* for architecture and the structural industries, and the *bergschulen* for the mining industries. In general there are two classes of schools and programs under each type, the so-called ''higher'' type which requires a superior academic preparation and leans strongly toward the technical side, and a ''middle'' type which leans toward the operating and supervisory side. These distinctions, however, are less marked in the *baugewerkschulen*. The schools for other industries are of a more composite character.

The *maschinenbauschulen* are the most numerous of the several types. Germany has twenty of the ''higher'' type and eighteen of the ''middle'' type under state and municipal auspices, as well as ten of the former and six of the latter under private auspices, making fifty-four in all. There are forty-nine *baugewerkschulen* giving programs of the higher type in Germany, many of which also give courses of the middle rank. The *bergschulen* are numerous in the mineral basins, Prussia alone having thirteen, of which four give courses of the higher type. Sweden has five higher schools and six middle schools, as well as two mining schools of the latter rank, all under state control. Switzerland has seven *technika* of diverse types, mostly under cantonal auspices.

The Maschinenbauschulen.—The higher and middle types of schools are seldom combined in a single institution. The two teach many similar subjects, but on different technical levels, and the middle schools in recent years have taken an increasing orientation toward management rather than design. The higher schools are recognized by the *Datsch* as engineering schools and their graduates are accepted by the *Verein Deutscher Ingenieure* after five years of additional experience. Those who wish to pursue higher professional studies are eligible to attend the technical universities as auditors, but may not take the examination for the professional diploma. The certificate of the *obersecunda* examination is normally required for admission, with two years of subsequent experience along rather closely specified lines, but others with four years of experience may also be admitted on passing entrance examinations in German, mathematics, and science equal to the *obersecunda* standard. About three-quarters of those admitted are of the former type. The normal age of entrance lies between eighteen and nineteen. The middle schools require certificates from the *volkschule* and the continuation school and four years of experience, the greater part of it in the industry for which the applicant wishes to prepare. The entering students range from eighteen to twenty-one.

The *Datsch* has described the functions of the higher and middle schools for the machine industries as follows:

> "The Higher Industrial School (*Höhere Maschinenbauschule*) should give its students a training which will fit them to be successful mechanical technicians in designing offices, in the direction of machine building shops and in similar technical works,"
>
> "The Middle Industrial School (*Maschinenbauschule*) should give its students a vocational training which will prepare them as future supervisors of workshops, proprietors of small concerns or as technical assistants in designing offices and in management."

Characteristics of the Higher Machine Schools.—The higher schools usually have semi-distinct divisions for mechanical and electrical engineering and some of the larger schools add one or more divisions in some such kindred fields as fine mechanisms, naval architecture, marine engineering or metallurgy. The courses of study cover five semesters of twenty weeks each, with a weekly attendance ranging from 40 to 44 hours per week. The laboratories, as a rule, are excellent, carefully planned for teaching rather than research, and admit of semi-individual work on the part of all students. One is impressed by the definitely technical quality of the teaching of mathematics, physics and chemistry. The special rooms for the two latter subjects serve as combined classrooms and laboratories and the experimental work deals almost wholly with technical mechanisms, instruments, materials, magnitudes and situations. On every hand there is an abundance of material for visual education—models, machine parts, cut-out machines, specimens of defective workmanship and design, charts, and diagrams—an art in which Germans seem to surpass all other peoples. Most of the classrooms are fitted with individual drawing tables. No separate drafting rooms are provided; in many cases each section of students has its permanent room, each student his permanent desk, and the teachers of all but the laboratory subjects come and go according to the time schedule. Under this plan there are no large lecture courses. All instruction is given in sections ranging from 15 to 40, with an average of perhaps 24. The teaching is *seminaristisch,* that is it is a combination of exposition by the master and discussion between the master and the student. Practically no instruction is given from textbooks; direct methods prevail and the teacher is the primary source; but manuals of reference for subsequent use are rather widely employed.

The instruction, as a rule is not highly mathematical. The work in mathematics proper, which extends somewhat into calculus, is geometrical in its emphasis and concrete in its teaching material. The students are habituated from the beginning to graphic language and analysis and quickly acquire a skill in presentation which is admirable. Comparatively little time, however, is spent in making carefully inked plates; trust German sense of economy for that! No attempt is made to teach the practical operations of mechanical and electrical construction—these must be learned in practice. The rather excellent collections of machine tools are used as laboratories, pure and simple, the machines being fitted with indicating and recording instruments which enable the students to study their performance in a critical manner.

As the programs call for forty hours or more per week, the work is largely done on the school premises under supervision. The outside work consists chiefly in the transcription of notes, the working of practical exercises and projects, and the preparation of laboratory reports. The latter, as a rule, are fairly simple memoranda rather than extended memoirs. There is none of the *lern-freiheit* of the universities. Students are required to attend all their assigned exercises and perform their work punctually. Grades and promotions are based on daily performance and on term examinations. The standards are comparatively strict and there is a much larger degree of elimination in course than in the universities. As a rule the number of graduates ranges from 45 to 60 per cent of those admitted. A jury appointed by the Ministry, but including representatives of the school staff, gives a comprehensive final examination, partly written and partly based on an inspection of the student's portfolio of drawings, reports, and other practical exercises. Success in this examination makes the graduate eligible for certain civil service appointments, but no professional title is conferred.

The Middle Mechanical Schools.—The facilities and methods of the middle schools resemble those of the higher schools, except for the difference in the technical level and the orientation of the instruction. More attention, as a rule, is given to what is called mechanical technology, or the practical processes of mechanical industry. For example, the *maschinenbauschule* at Essen has comparatively modest laboratories of heat engines, electrical machinery, hydraulic machinery, etc., but has a more extended machine tool equipment than the higher schools and an excellent laboratory of autogenous welding. The mathematical instruction is definitely practical in character; there is an extended review of arithmetic, with especial reference to the calulation of interest and costs, to the use of tables, to interpolation, and to the use of computing machines. Algebra, plane geometry and trigonometry are covered selectively for their mechanical and management applications. The work in the third semester has largely to do with graphic representation and the mathematical uses of handbooks.

Examples of Curricula of Maschinenbauschulen.—*Typical* programs have been selected from the mechanical and elec-

CURRICULA OF HÖHERE MASCHINENBAUSCHULE, HAMBURG

Mechanical Section

	Semester				
	I	II	III	IV	V
	Hours per Week				
Mathematics	10	6	4		
Mechanics	10	10	6		
Chemistry	4				
Projection drawing	6				
Industrial hygiene	2				
Machine drawing and design	10	12	4		
Mechanical technology	2	4	4	4	2
Acoustics and optics		2			
Thermodynamics		2	4		
Laboratory of technical physics			4		
Electrotechnics		4	4	2	
Hoisting and conveying machinery		4	6		
Boilers			4	4	
Steam engines			4	6	
Internal-combustion engines				4	
Steam turbines				4	
Electrotechnical laboratory				2	4
Building construction				2	4
Pumps and water turbines				4	2
Political and social economy				4	6
General options				2	2
Special branches of machine construction					4
Chemical laboratory					2
Autogenous metalworking					2
Design projects					12
Mechanical laboratory				6	6
Total	44	44	44	44	46

Electrical Section

	Semester				
	I	II	III	IV	V
	Hours per Week				
Mathematics	10	6	4		
Mechanics	10	8	4		
Chemistry	4				
Projection drawing	6				
Industrial hygiene	2				
Machine drawing and design	10	12			
Electrical technology	2	4	4	4	2
Acoustics and optics		2			
Electrical science		8	6		
Thermodynamics		2			
Electrical measurements		2	4		
Laboratory of technical physics			2		
Building construction			4		
Power machinery			6	6	
Electrical machinery			8	10	12
Electrical communications			2	4	
Social and political economy				4	6
General options				2	2
Electrical installations and layouts				8	4
Laboratory of electrical machinery				4	8
Laboratory of electrical communications				2	4
Special applications of electricity					4
Mechanical laboratory					4
Totals	44	44	44	44	46

trical sections of the higher mechanical school at Hamburg and from the section for fine mechanism at Esslingen. The example of a middle school program is from Essen. There are many local variations. The State Ministries, as a rule, prescribe or approve the course schemes. No effort has been made to bring them all into conformity, but the German tendency to adhere to common types and traditions holds the programs of common rank within fairly narrow ranges of diversity.

Section for Fine Mechanisms (Esslingen)

	Semester				
	I	II	III	IV	V
	Hours per Week				
Economics, Civics	2	2			
Mathematics	8	6	4		
Descriptive Geometry	6				
Physics	8	2			
Chemistry	4				
Technical Mechanics	4	4	6		
Strength of Materials	4	4			
Machine Drawing	6				
Mechanism and Machine Elements		8	4		
Metallurgy		2			
Pattern Making and Foundry		2			
Surveying		2			
Elements of Electrotechnics		6	6		
Physical Laboratory		2			
Chemical Laboratory		2			
Thermodynamics			2		
Hydraulics			2		
Mechanical Materials			4	2	
Structures			2		
Technical Measurements			6		
Electrical Machines			2		
Materials Laboratory			2		
Electrotechnical Laboratory			2		
Industrial Management				4	2
Tools and Instruments				8	
Machine Tools				4	8
Design of Elements				12	
Design of Instruments and Apparatus					16
Manufacture				4	8
Heavy Current Electrotechnics				2	4
Electrical Communications				4	2
Acoustics and Optics				4	
Theory of Machines					4
Optional Study	2	2	2		
Total	44	44	44	44	44

Curriculum of Middle Maschinenbauschule, Essen

	Semester			
	I	II	III	IV
	Hours per Week			
German, Civics, Economics	4			
Mathematics	15	5	2	
Physics	6			
Chemistry	2	2		
Drawing	11			
Mechanics		5	4	
Mechanism and Machine Elements		16	4	
Power Machinery			9	
Electrotechnics		4	4	
Industrial Plants			2	
Industrial Technology	2	6	7	
Hoisting and Conveying Machinery			2	
Exercises in the Laboratories		2	6	6
Total	42	42	43	43

Purpose and Character of the Baugewerkschulen.—These schools bear the same relation to the construction industry as the *maschinenbauschulen* to the mechanical and electrical industries. In fact, it is said that fully nine-tenths of the buildings erected in Germany are designed and executed by men trained in the *baugewerkschulen.* These schools have virtually created the domestic architecture of Germany, so distinctive and homogeneous yet free from monotony, and are the most active agents in its further development. The purposes of the schools, as set forth in the official circular of the Prussian Ministry of Commerce and Industry are:

> "(*a*) to give managers of construction work who wish to perfect themselves in architecture or technical construction, especially masons, carpenters and stone workers, the opportunity to acquire theoretical knowledge and ability in drawing and design which are needed for the independent practice of their callings;
>
> "(*b*) to train architectural and technical assistants for offices and field works (*bautechniker* and *bauführer*); and
>
> "(c) to prepare officials for the technical services of the federal, state and municipal government."

Whereas the technical universities teach architecture and structural engineering on a comparatively ambitious scale, the *baugewerkschulen* put their emphasis on the design and construction of the utilitarian structures of everyday life, farmsteads, dwellings, apartments, schools, industrial buildings, single-span bridges, small water powers and the like. Modern forms are everywhere emphasized, while monumental construction and gothic and classical forms and ornament receive only incidental treatment. Much attention is paid to the economics of building, both in distinct courses given to the subject and in the more technical branches. A number of the schools have short courses for surveyors.

The schools are organized and their teaching conducted in a manner much like the higher machine schools. For admission to the higher courses the *obersecunda* certificate is required or an equivalent examination and two years or more of building experience divided between the field and the office. The laboratories are less extensive than in the mechanical schools, but the collections of structural parts, samples of materials, pictures, drawings and casts are often elaborate. The student is taught to think from the outset in graphic terms and forms and quickly acquires a rapidity and excellence of presentation which amazes an American visitor. Instruction is given in small classes in rooms fitted with drawing tables, each student having his own permanent post. The admissions are limited and to a considerable degree selective.

There are forty-nine schools of this type in Germany, twenty-six of them in the State of Prussia. The enrollment ranges from 200 to 600 per school. The principal programs are five semesters in length, the minor programs one year. Each semester normally occupies twenty weeks. Promotion from semester to semester is based on daily work and term examinations. The State gives a final examination, directed by a jury, the principal purpose of which is to determine the eligibility of graduates for civil service appointments. However, no professional title is conferred.

Typical Curricula of Building Schools.—Many of the schools have separate sections for architecture (*hochbau*) and for technical construction (*tiefbau*). Others, like the admirable school at Stuttgart, give only a single major program. Stuttgart, however, has a post-graduate program of one year in hydraulic engineering (*wasserbau*). The following examples of the architectural and technical programs are taken from the official regulations issued by the Prussian Ministry of Commerce and Industry for the twenty-six *baugewerkschulen* under its direction:

Curricula of Prussian Baugewerkschulen

	Semester and Section							
	Common		Hochbau			Tiefbau		
	I	II	III	IV	V	III	IV	V
Conduct of Business	2	2	2			2		
Civics	2	2	2	2	2	2	2	2
Mathematics	9	6	2			3	2	2
Physical Science	2	2	2			2		
Perspective	3			2	2			
Free Hand Drawing	2	2	2	2	2			
Lettering	2	2	2			2		
Architectural Drawing	7	6	6	4	4	5		
Architectural Forms	2	2	2	4	3			
Model Making	2	2	2				4	
Building Construction	7	7	6	9	4	4	2	8
Building Materials		2	2		2	2		2
Mechanics of Structures		3	3	4	5	4	4	5
Surveying			2			2	4	
Plans and Equipment	2	2	5	3	4			
Economics and Management		2	2	4	4	2	4	4
Electives	2	2	2	2	2	2	2	2
Projects				8	10			
Municipal Engineering							4	4
Hydraulic Construction							4	5
Bridges						2	4	3
Steel Frames						2	2	
Foundations						2		
Reinforced Concrete						2	2	3
Earthwork and Railroads						4	4	4
Total	44	44	44	44	44	44	44	44

Five of the Prussian *baugewerkschulen* give a two-semester course in surveying with the following program. The minimum age of admission is 17 and candidates are required to have a good *volkschule* and continuation education.

CURRICULUM IN SURVEYING, PRUSSIAN BAUGEWERKSCHULEN

	Hours per Week	
	I	II
German and Business Practices	2	2
Civics	4	4
Arithmetic	2	
Algebra	4	3
Geometry and Stereotomy	4	3
Trigonometry	3	4
Physical Science	2	2
Lettering	2	
Projection Drawing	1	
Surveying and Levelling	8	12
Plotting	6	8
General Construction	6	4
Aerial Surveys	1	
Total	45	42

The *höhere bauschule* at Stuttgart has a post-graduate curriculum in hydraulic engineering, which occupies two semesters;

POST-GRADUATE CURRICULUM IN HYDRAULIC ENGINEERING,
HÖHERE BAUSCHULE, STUTTGART

	Hours per Week	
	I	II
Applied Mathematics	4	
Electrotechnics	2	
Geology	4	
Power Machinery	4	
Practical Geometry and Surveying	6	4
Hydraulics	4	4
Hydraulic Computations	2	
Hydraulic Construction	6	6
Hydraulic Power Development	6	10
Water Supply	2	4
Piping Systems		4
Applications to Agriculture		4
Safety and Industrial Hygiene		2
First Aid		1
Total	40	39

The Bergschulen.—The schools of practical mining are operated on a part-time plan whereby the students continue their work in the industry from four to six half days per week during the school year and work full time during the summer. Two grades of instruction are given: the *steiger* courses are intended for the training of foremen for the underground, above-ground, mechanical and electrical departments respectively; and the *oberklasse* is of a more advanced grade for graduates of the *steiger* courses who wish to qualify as superintendents. Professional mining engineers are trained at the technical universities and higher mining schools.

To be admitted to the *steiger* class the applicant must be not less than 21 years of age and, as a rule, have completed the course in a *bergvorschule* or have the *obersecunda* certificate from a secondary school. The *bergvorschule* is a part-time continuation school for graduates of *volkschulen* employed in the mining industry. The candidates must also have had four years of active mining experience. Candidates for the *oberklasse* must be between 25 and 35 years of age and must have had at least one year of experiene in the official ranks. Furthermore, they must hold a certificate of completion from the *steiger* class with a rank not less than ''good'' or pass an entrance examination.

Examples of Bergschule Curricula.—The following examples are taken from the *Bergschule* at Bochum in the Ruhr, the largest and most prominent of the schools for the coal mining industry:

CURRICULUM FOR MINE FOREMEN, BOCHUM

	Semester				
	I	II	III	IV	V
	Hours per Week				
Mathematics	4	2	2		
Mechanics	2	2	2	2	
Materials	2				
Drawing	4	4	4	2	
Physics and Chemistry	2	2	2		2
Mining	3	7	3	4	6
Civics and Mining Law	1	1	1		
Surveying and Mapping	2	2	2	2	
Mining Machinery			2	4	4
Electrotechnics				2	2
Management					2
Total	20	20	16	16	16

Note: The classes are held in two divisions; one group spends the morning in the mines, the afternoon in the school; the second, vice versa.

CURRICULUM FOR MINE SUPERINTENDENTS (OBERKLASSE), BOCHUM

	Hours per Week	
Mining Operations	4	4
Industrial Law and Economics	2	2
Coal Preparation	2	2
Mathematics and Mechanics	2	2
Mining Machinery	4	6
Electrical Machinery	4	4
Mine Surveying and Mapping	4	4
Mineralogy and Stratigraphy	2	
Geology	2	2
Physics and Chemistry	4	4
Drawing	4	4
Total	32	32

Note: Members of the *oberklasse* work two full days per week in the mines.

A Leading Textile School.—Only a single example can be chosen of the many schools which prepare for specific industries. The *Technikum für Textilindustrie* at Reutlingen is maintained by the State of Wurtemburg and is one of the most widely known schools of its class in all Europe. It has close working relations with the technical university at Stuttgart which permit students of the latter in the mechanical division to spend one or more semesters at Reutlingen in order to gain special qualifications in textile engineering. The *Technikum* has in operation a complete textile manufacturing plant, covering all the operations from the preparation of the raw materials to the manufacture of cloth, knit goods and certain lines of sewn and embroidered articles. Divisions and courses are organized as follows:

Spinning Division	1-year Course
Weaving Division	1-year Course
Sewing and Embroidery	1-year Course
Division for Designers	2½-year Course
Chemical Division	2-year Course
Course for Salesmen	½-year Course
Bleaching, Dyeing, Printing and Finishing	Short Elementary Courses for the Mechanical Divisions
Commercial Course	1 Year, 2 Hours per Week

Status of Teachers.—The salaries, titles and schedules of the teachers in the higher and middle industrial schools are virtually the same as those of teachers in the higher types of secondary schools. These appointments are eagerly sought after, as they carry a desirable social position, a fairly comfortable salary, security of tenure and the privileges of a state pension upon retirement. The rosters of the several schools show a higher proportion of doctors of philosophy and of engineering than all but a very few of our engineering colleges. In a few of the states the higher teachers are allowed to use the title of "professor"; this practice, however, is being discouraged and the title of *studienrat,* or counsellor of studies, is coming into general use.

The work loads are fairly heavy, averaging about 24 hours per week for a teaching year of ten months, with preparation and correction in addition. As a rule there is only a small margin of time for practice, research or scholarly work and the production in these forms is of distinctly creditable amount and quality. A few of the schools have special research institutes, as that for low-head hydraulic motors at Esslingen, but this condition is exceptional. Systematic teaching is stressed and original work left largely to the universities.

As a concrete example of the status of teachers, the terms of appointment at Hamburg are as follows: candidates are expected to hold the diploma of engineer or a higher degree, to have had five years or more of practical experience, and to pass through a probationary appointment before being given a permanent status; their salaries rise by steps to a maximum of 11,000 marks ($2,750) per year, which affords a place in the social scale—though not in the scale of buying power—corresponding approximately to about twice that salary in the United States.

Costs and Fees.—The costs per student per year of the higher machine schools and building schools of the states of Prussia and Hamburg were stated officially to average between 800 and 850 marks, or about half the unit costs of the technical universities. In the same institutions the annual tuition fee is 80 marks, the remainder being made up by the State. These data are typical of the entire public system. The private schools, most of which are entirely dependent upon their fees, are having a difficult time to survive in the face of the generous support given to the State schools.

Appreciation.—In the author's judgment nothing in the entire educational system of Central Europe has more value as an example to America that these admirable schools, with their clear perception of practical aims, their direct methods, their efficient use of time and equipment, and their integration of teaching with industrial experience.

D. CONCLUSION

General Observations.—Technical science is pursued with an intensity in Central Europe which is little known in America. What Germany and Switzerland lack in space and natural resources they endeavor to make up by supremacy in the arts of refining and fabrication. In Scandinavia, where economic pressure is less severe, technical science is invoked to maintain general comfort at a high level with limited resources. American interest in engineering has centered in the exploitation of resources and markets assumed to be limitless, with less incentive to high economic utilization than to boldness and originality in the face of natural difficulties. Furthermore, crowded populations are necessarily more closely regimented into professions and vocations, with less freedom for individual initiative.

The social and economic ends of technical education are sensibly different in the two areas. Ours is conceived as an aid to the progress of individuals of varying needs and tastes, and only secondarily as a processs of recruiting well defined callings. Our technical professions have no codes of qualifications which make for definiteness of educational aims and standards. Not so in Germany or elsewhere in Central Europe; there technical education is a definitely organized arm of the body economic, controlled by the brain of the system—the State. Standards are set objectively by State examinations; technical education is graded; each type of diploma carries certain career privileges and limitations; and it is difficult to rise from one caste to another by sheer force of personality. Because their aims are more clearly visualized, their educational system is more logically organized. For both reasons it is more efficient in some respects, and in others attains an efficiency equal to our own at far less cost in paternalism.

The professional training of the technical universities goes beyond our own in a number of particulars. The preparation for entrance is more advanced by one or two years, and in general more selective. The program is virtually nine semesters, plus a year of required experience. The general technical sciences, especially mechanics, are introduced early so that far more time remains for training in the constructive side of engineering. The professors are men of a higher degree of specialized experience and attainments. The pace of instruction concedes little or nothing to the slow and mediocre. The net result is that the time devoted to technical as distinct from fundamental training and exercises is two to three times as great as in the American program and makes a correspondingly greater demand on original constructive ability. The less extended manipulative experience of the undergraduates is offset in degree, if not in kind, by the vastly greater total and the higher scientific level of post-graduate research.

Greater independence has enabled our colleges to progress further toward a solution of education for industrial management, but we are backward in research on the underlying problems and have little to compare with the active work of their research institutes of psycho-technics and of machine tool technology.

It is an open question whether the more precise professional training of the German engineer results, in the last analysis, in greater benefit to the economic order than the greater individual adaptability of the American. Our graduates show a far wider spread of activities and greater penetration into administrative posts; many whose scientific qualifications were never high, have been good missionaries for technical progress in their commercial and executive callings.

The *maschinenbauschulen, baugewerkschulen* and *bergschulen* have few counterparts in America, where we seem unable to think in any other terms than "college" and "trade" education and commonly take it for granted that formal education should normally be a continuous process from beginning to end. The author feels that these institutions have a more immediate lesson for us than have the technical universities. Until we have created schools of a comparable character for the higher practical pursuits of technical industry, with facilities and enrollments fully equal to our 100 best engineering colleges, it will be difficult or impossible to raise the scientific and professional level of our college instruction much above its present compromise level.

We can have only admiration for the responsible and constructive part taken by the engineering profession in the direction of technical education in Germany. It is remarkable that in an essentially bureaucratic system, the profession has voluntarily built up its influence to a level fairly equal to that of the State and has given it so effective an instrument as the *Datsch*. Technical education has unlimited freedom in the United States, but is left to grope its way and to fend for itself. Herein are potentially its greatest strength and its greatest weakness, for educational progress depends not alone on experiment and innovation, but equally on clearly visualized aims for both the schools and the professional body.

Germany's greatest lesson for American technical education undoubtedly lies in the qualifications and scientific activities of her teachers. She has not deemed it too costly, but a wise economy of resources, to attract and hold her most creative minds to university posts. It is clear that Germany has risen from disaster and disillusionment impoverished, but undismayed, determined to make for herself a great economic future. To do this she must sell to the world the labor of her people, enhanced to the utmost by scientific intelligence. One notes a well organized effort to rouse the enthusiasm of youth for technical and industrial pursuits. The incomparable *Deutsches Museum* of Munich, devoted entirely to the technical sciences, is one of the most effective agencies to this end. The guidance publications of the *Datsch* are also worthy of special mention. There are indications that the old enthusiasm for military pursuits has been successfully diverted into these new channels; for example, the enrollments in the faculties of mechanical and electrical engineering were quadrupled in 1924 as compared with 1914, by far the greatest increase of any branch of higher education. Beyond all doubt, Germany is spending more in proportion to her means on technical education and research than any other of the great economic powers. It would be untrue to the facts to suggest that all is progress and prosperity; there are eddies and backwaters in the stream-antiquated plants, overcrowded amphitheatres and laboratories, lack of facilities for individual work, professors isolated during the war and outdistanced in their specialties, ineffectual teachers—but the main current rolls on with an impression of quiet but irresistible power.

PART V. THE AMERICAN SCENE

This final section is an attempt to view, and in some measure appraise, the higher technical education of the United States in a spirit of detachment, by comparison and contrast with the European systems which have been briefly described.

A National System Without Plan.—The higher forms of technical education have developed sporadically in the United States and without an underlying plan. In the absence of any federal authority or any central control of technical education by the states, each institution has developed with complete freedom. It is surprising, therefore, to find so little variety of types of instruction and of levels of entrance and completion among the one hundred fifty colleges of engineering, and so few substantial technical schools of any other type. Tradition, the influence of early models and imitative growth evidently may impose even greater uniformity than bureaucratic authority. The aim of the original technical schools ''to promote the application of science to the common purposes of life'' was comprehensive but vague, and was quickly transformed into more precise but limited terms when the advent of the railroad created a specific need for engineers with a scientific training. The new discipline, formed on French models, was quickly assimilated by the collegiate system as an alternative to the older discipline in liberal arts. This transpired in a formative era of our national educational system when a simple but artificial order was being standardized—the elementary school, the secondary school, and the college. Technical education fitted into only one of these compartments, the college. There it grew vigorously, but the total result has been most one-sided.

Moreover, one dominant type tended to overpower all others. Repeated attempts to create and maintain other forms of technical schools, with briefer, more practical and more flexible programs, have ended in most cases in final absorption into the college group. Being neither primary schools, secondary schools nor colleges, these less conventional technical schools seemed to have no place in the national system. Their graduates had no credentials of wide acceptance, and no professional or educational bodies of wide influence extended recognition or encouragement. Immigration supplied a steady stream of skilled labor and of trained technicians. As long as America provided means whereby her native youth might be trained for the recognized engineering professions she was content.

The Directive Forces.—The guiding forces have come almost wholly from within the system itself. The early pioneers were educators and scientists who visioned the potentialities of applied science, rather than statesmen bent on economic reform or practitioners seeking to train subordinates. They did American education an inestimable service by breaking the monopoly of classical learning, introducing more concrete forms of instruction and directing it to economic ends. The State has had little formative influence; the Morrill Act provided means for a vast extension of technical education, but did little in itself to create a type. The technical professions and industries have been consumers and critics rather than responsible guides. The traditions of the engineering profession have been individualistic, its definitions loose and its code of qualifications based solely on ability to perform. These conditions have reacted strongly on technical education, but in a negative manner. It has been left to grope its way and fend for itself, in marked contrast to the technical education of France, Great Britain, and Central Europe.

The Central Aims.—Technical education abroad is essentially national in plan and in outlook; it is definitely tied in with the economic system; and is controlled by public authorities and the organized professions. American technical education is individualistic in its aims and ideals; its primary concern is with the welfare of the student, its secondary aim to recruit a group of professional callings; in consequence it is at best only semi-selective and semi-professional. American engineering colleges have less precise aims and functions than similar institutions abroad. They can not fit men into pre-determined molds nor form them to conventional professional patterns; the ideal must be one of personal adaptability

—in some measure the ability to go anywhere and do anything, not always with ultra-expertness, but sufficiently well for practical purposes. They can not, if they would, put aside their task of personal guidance and social adjustment, their concern with the entire life plan of the student as an individual, for which little need exists in the highly stabilized societies abroad. The chief danger, however, seems to lie in the opposite direction, that a benevolent paternalism may be overdone and the compromise between the ideals of social adjustment and those of a selective professional discipline may result in the technical professions being outranked intellectually both at home and abroad.

Quantity Production and Intellectual Standards.—The burden of quantity production for the ordinary technical, supervisory and commercial needs of industry weighs heavily on the American engineering colleges. Efforts to create highly selective schools of distinctly superior scientific standards have fared badly as a rule. No institution is so outstanding that the success of such an effort could be taken for granted, as long as the public mind differentiates the engineering schools chiefly by the excellence of their plants and the size of their enrollments, rather than the eminence of their teachers, the scientific quality of their instruction or the merits of their research. The distinction which is universally made abroad between preparation for the practical direction of industry and for its intellectual leadership, has not been recognized—America has neither *Arts et Metiérs* nor *Ecole Polytechnique.* One result has been that the production side of industry has been seriously underrecruited; another that in the constructive industries America has been dependent for the highest forms of analytical and design ability on men trained abroad. Technical research has depended in large measure on men of European training or upon men trained in pure science. These conditions are gradually being corrected, but American engineering is still far from being self-sufficient on its higher intellectual levels.

It may be remarked that American technical superiority in the realm of mass production and automatic processes has been achieved almost wholly within industry itself and owes little directly, or perhaps even indirectly, to the schools of engineering.

Preparatory Education.—The demand for educational privilege and the problem of assimilating a population of heterogeneous origins have been so insistent that the entire educational system has been expanded with little regard to the availability of a qualified teaching force. The pressure has been acute in secondary education and its effects have been severely felt in the colleges. It is a safe generalization that the standard of intellectual and cultural qualifications among secondary teachers abroad is quite equal to the average found in our higher institutions. Considering that secondary education abroad is a selective process, definitely pointing to intellectual pursuits, covers a period of six to nine years, is organized on a much more intimate scale, and involves much greater continuity of subject matter, it is not surprising that the levels of intellectual achievement are decidedly superior to our own. Our public secondary schools disclaim a predominantly intellectual purpose, and are preoccupied with exploratory processes and social guidance activities, intended to fit young people into spheres of life quite unlike those in which they were born and reared.

It is probably too much to ask that our preparatory education shall reach the levels of intellectual efficiency of the highly selective systems of Europe, but it seems clear that the present levels of achievement at the age of twenty or twenty-one could be reached at eighteen or nineteen by young persons of superior endowments without sacrifice of youthful vitality or zest. A study of European experience lends strong support to the conclusion that the most effective means to a broader scientific and humanistic education for engineers, which every one agrees is needed, is through more effective secondary education and more selective admission, rather than delayed entrance into technical studies and pursuits. World wide experience and the clearly expressed judgment of the engineering profession indicate that the age level between sixteen and nineteen is a normal period for beginning technical education, and that from twenty-one to twenty-three for entrance into practical pursuits. The present quality of our mathematical and scientific preparation is so low that it constitutes the greatest handicap of our engineering colleges in comparison with similar institutions abroad.

Curriculum.—Conservatives who hold to an orderly discipline in technical education may find assurance in the fact that Europe has discovered no effective substitute, even where the greatest autonomy prevails in purely academic studies. Radical departures from the organic unity of a curriculum which begins with the mathematical, physical and natural sciences and proceeds from the basic technical sciences to their engineering applications, such as a completely inductive case system, a sequence of job assignments or a complete submerging of the general sciences into the technical branches, are still to be regarded as experiments, postulated on educational theory rather than experience. Europe has not yet developed a phobia for preparatory studies on the theory that all education must grow out of immediate life experience. Considered purely as a formal educational structure the American curriculum will stand comparison with any abroad. It is distinctly broader than the English or Scottish examples, but the merit is more apparent than real when the limitations of our secondary education are considered and allowance is made for thoroughness of mastery and coordination of the basic sciences. It is far more elastic than the French scheme of courses with specialized objectives, as it should be considering the later career choices of American youth. It is more closely knit together than the German programs with their vast proliferation of specialized applications.

There can be little criticism of the sequence of studies, except that mechanics is introduced so late in many cases as seriously to hamper and restrict the development of the engineering subjects. So certainly is the place of mechanics the key to time economy, that it would seem worth while to restudy completely the sequence of topics in mathematics and the relation of mechanics to general physics with a view to its earlier introduction. Time allotments to mathematics, physics and chemistry are probably as large and the present treatment as encyclopaedic as can be justified for the average student, but higher standards of mastery of the comparatively few key principles are imperative all along the line, and provision should be made for more extended study of the general sciences by selected superior students. The latter end might appropriately be secured through advanced elective courses, adapted in content and pace to superior students, which may be elected as substitutes for courses in technical applications.

The limited study of engineering on its constructive side—in which we lag far behind the continental schools—is probably regrettable but inevitable. We can not afford the time, too few of our students are preparing with certainty for design work, our processes of fabrication are unsuited to ''custom built'' structures, and very few of our colleges have, or perhaps can have, fully qualified teachers. No solution of this problem is in sight but to make this phase of an engineer's education part of the professional novitiate, either by some cooperative plan between employers and selected graduate schools or by systematic training within industry. Here the electrical industries have pointed the way for the benefit of all.

Specialization.—The author is no advocate of a common curriculum for all engineers, but believes that differentiation on broad lines which parallel the major divisions of the technical professions is both expedient and sound. All European experience supports this view. The multiplicity of curricula and degrees reported by the U. S. Bureau of Education is less alarming when one recognizes that seventy per cent of all engineering students are in three major curricula and 83.5 per cent definitely within the areas of the five principal professional branches. The German plan of holding to a few major ''faculties'' and providing group options in the final years, some specialized and others broadly theoretical, seems wise and sound. The French plan of specialization by schools seems to imply a purely teaching aim. Certainly it has not engendered research through what has been called ''the mutual fecundation of the sciences.''

Teaching Processes.—In nothing does the essential juvenility of our higher education reveal itself so fully as in the text-book, daily assignment, recitation, written quiz, piecemeal grading system of instruction, and in our eager effort to compensate for the student's defective mastery of the processes of learning by one and another pedagogic device. In the effort to make up for deficiencies of preparation, the indefinite aims of students, the lack of social and economic urges to educational achievement, as well as the absence of intellectual traditions in society and of standards of scientific competency in the technical professions, the engineering colleges of America have felt compelled to resort to a driving process. The student has less freedom and more routine than his European confrere. He probably does not work any harder, but he works under a different regime and under different urges. He is not an independent spirit striving for a large but distant goal and imposing on himself the discipline needed to attain it, he is too often a harried quantity producer trying to keep abreast of his quota of daily and weekly tasks.

The author is convinced that education based on systematic execution of concrete tasks, interspersed with direct expository teaching, discussion and reflection, has merit—one has only to spend a day at a French *Ecole d'Arts et Metiérs* or a German *baugewerkschule*—but it belongs in a school definitely organized to that end, working on an all-day program. The actual methods of our engineering colleges, while less efficiently organized because not so clearly visualized, do not work badly with industrious students of rather mediocre ability. There is plenty of European testimony to the effect that we accomplish more with our average students than any other system. The superior student, whose originality and imagination are too often sacrificed to mere industriousness, is not so well served. Sweeping statements are always partially untrue, and exceptions to these observations are numerous, but the author is convinced that they are broadly true. The root of the problem is in the teacher, too often overloaded and only half prepared for much that he is expected to teach, who perpetuates the system of which he is the product and too often knows or imagines no other. We are not, as a rule, effective lecturers and have made little study of the art of giving instruction to large groups. Our students expect to be taught, rather than to learn independently with the guidance and coordination that an able lecturer can supply.

Our experimental and practical teaching is today probably as effective as any in the world. This statement may be qualified, however, by the comment that much of the time spent on shop practice could probably be spent to far greater educational advantage, that many schools are still teaching far more surveying than is warranted for all but a few civil engineers, that too much laboratory teaching is of little more than manipulative value, and that the scientific analysis of experimental results leaves much to be desired. Our leadership, it must be owned, tends to be quantitative, rather than qualitative, and is due in large measure to our far richer equipment. One who examines the laboratory reports of a fourth year man in say electrical engineering at Stockholm, Delft, Berlin or Zurich, soon realizes that our students spend much industry in manipulating, observing, descriptive writing and compiling, but little on the critical analysis of the project.

Training in Management.—From the days of Taylor on American leadership in applying engineering methods to industrial organization and process has been unquestioned. In consequence our technical education reflects a wider spread of engineering activity than is common abroad, especially on the management side. The unity and freedom of our higher educational system have made it easier to introduce the economic sciences into technical education than in the compartmental systems abroad. One must credit the French, however, with special success in training engineers in the art of command due, it is claimed, to a combination of rigorous selection, high intellectual formation, professional teaching by eminent practitioners, industrial *stages,* an officer's training with the army, and—far from least—the confidence and solidarity bred of being a *Polytechnicien.*

Our curricula in industrial engineering and management are attracting wide attention abroad. Only occasionally, however, does one meet an attempt to work out the problem through a separate professional department or curriculum, as at Manchester. The Germans, who are now particularly active, are giving considerable place to both teaching and research in management matters under their regular technical faculties. Many of the same problems are met on both sides. Qualified teachers with responsible experience in management are hard to find and the revamped economist, psychologist or statistician is no nearer to the engineering ideal there than here. Teaching materials are not yet effectively organized, since management is still from being a mature and orderly science and the verdict of experience is yet to be had on the value of teaching its few generalized principles—many of them sublimated common sense—and its many detailed expedients. Higher education for business is not going any too well abroad and is far from being the rival of technical education that it is in the United States. Technical educators abroad are no clearer than we on how far to go and what methods to use in orienting the engineering student to executive and personnel problems. The Germans seem clear on one point at least, that research on the problems of selection for industrial vocations and on the laws governing the efficiency of human work, especially when coordinated with mechanical processes, properly belongs to the technical universities and requires the collaboration of engineers and psychologists. From their insistence that such research must come first and teaching follow we might learn a wholesome lesson.

Technical Research.—It is a fair generalization that in matters of technical research our institutions are far in advance of those of France and other Latin countries, on a par with Great Britain, and definitely behind Central Europe. Parity with Great Britain, however, is not an occasion for boasting, when the vastly greater scale of our university organization is considered. It is only in the last two or three decades that research has been regarded as more than an incident in the work of our engineering colleges. Our backward state, despite relatively heavy expenditures, is probably an inevitable phase of early effort. There are still relatively few men of high research capabilities in our professorial chairs; industry has requisitioned many of the most fertile for her own fast growing research establishment; and until quite recently there has been far greater incentive to textbook writing and to incidental practice than to research. Research personnel can not be improvised; that of the German institutions is the product of a century of cultivation and selection, backed up by a powerful tradition. With the fullest allowances for the difficulties of pioneering, one can not say that the matter of research has been handled by the engineering colleges in a highly statesmanlike manner. It was only rarely that the growing need was anticipated. Industry, meanwhile, having discovered the potency of research as a competitive weapon and a publicity asset, has become definitely committed to research on its own account. The policy of the colleges has been a scattering one, growing out of friendly rivalries between individuals and institutions, and less effectual than the more concentrated effort abroad. Has it been better to bring a large area under some degree of cultivation, or should we have attempted to work a few selected plots intensively? Only time can tell. At any rate, the opportunity to make the engineering colleges the chief centers of technical research seems to have passed. The Germans, whose life depends on maintaining technical pre-eminence, have little fear of the competition of our universities, but that of our industrial research laboratories is giving them serious concern.

It would seem that the development in our engineering colleges of a strong spirit of inquiry and creative effort is of much more fundamental importance than changes in the form, content or length of our curricula. Good students largely educate themselves if environmental influences are favorable. We need to be delivered from too much faith in educational routine. Pure scientific research is an indispensable adjunct to technical research, but not a substitute. One has only to consider the present situation in physics where interest is centered almost exclusively on sub-atomic phenomena, while the molecular phenomena on which much of engineering depends are almost wholly neglected.

Status of Engineering Teachers.—This is a delicate question, but one to be faced frankly. It is a safe generalization that the engineering professor occupies a place of higher prestige and influence in each of the ten European countries which the author visited than in the United States. In the aggregate our faculties include a considerable group of engineers of the highest ability and distinction. Wide observation abroad leads almost inevitably to two basic conclusions, (1) that a large proportion of American teachers of engineering are attempting with great industry and devotion a task for which they are inadequately prepared either by scientific training, professional experience or broad personal culture; and (2) that the technical professions and industries of America have not attached great importance to placing and keeping men of the highest fertility at the chief sources of their recruitment. It is difficult, of course, to uphold standards among teachers which are much above those prevailing in the profession at large unless the major posts are invested with high prestige, wide freedom and reasonable affluence. Here Germany has succeeded in large measure, while we have scarcely envisaged the problem. Apparently we are due for a radical change in our thinking. American industry, as a whole, has been pitched to only a moderate scientific level but is now advancing rapidly. In the competition with industry for creative scientific ability teaching has steadily lost ground for nearly twenty years. Educational executives are making greater efforts to cope with the situation, but are hampered by limited funds and by the hangover of a tradition that teaching may safely be left to men of great personal devotion but of comparatively routine ability.

It is impossible to raise the level of the entire body at once. It would be almost invaluable, however, if ten or a dozen institutions could immediately be put in an outstanding position so far as salaries and qualifications of personnel are concerned. The present rise of scientific standards was not anticipated in the training of many teachers in middle life who, under our conditions of tenure, will remain in front line positions for many years to come. The immediate problem is to increase the amount and raise the level of post-graduate training in our dozen best qualified institutions; to send selected men abroad for work in special fields where we are backward—*vide* the Freeman fellows in hydraulic construction; to induce industry to send selected and tested young men from their technical staffs back to the graduate schools; to keep our most promising men free from the deadening influence of routine and to stimulate them to scientific creation rather than pot-boiling; and to pay them well enough to remove the temptation to enter industry for the sake of reasonable comfort and recognition.

On the other hand, American teachers of engineering merit a glowing tribute for their zeal in the study and improvement of the teaching process. Here the burden of world leadership clearly rests upon them, partly because of the handicaps of preparation and preliminary selection under which they labor, but more largely because American education, more than that of any other country, centers in the individual welfare of the student.

Student Life.—Wide observation at home and abroad confirms the belief that there are values worth preserving in the multifarious activities of our student life. The extreme mobility of our social system makes it essential that our youth shall have opportunity for self-discovery and personal experiment outside of the academic sphere. The large proportion of our engineering graduates who ultimately hold business and executive responsibilities is probably due in no small measure to interests discovered and abilities tried through student activities. The problem which confronts us is wholly one of proportion. The author believes it to be most unwise to load engineering undergraduates so heavily with routine and detail that a normal, healthy participation in activities is denied the average man. In these matters we have little to learn from France, Germany or elsewhere on the continent of Europe.

The English system of sport, however, is far more wholesome than our high-powered competitive athletics. America is the paradise of the self-supporting student; the attitude abroad is unfavorable to diverting so large a measure of energy from the main objectives of education. As intellectual competition grows keener in our industrial life we may have to consider whether it would not be greater economy to provide much more generously for ''loans of honor'' and for the payment of college fees by deferred installments or to extend much more widely the cooperative plan, than to depend so much upon casual earning power.

Integration of Academic and Practical Training.—But for the cooperative plan our record on this score would not be particularly creditable. In theory our technical professions uphold the principle that practical training is the indispensable part of an engineer's education; in practice, their attitude toward it is distinctly casual, leaving it to the individual to work out as best he can. The British and Germans particularly insist that practical training shall have form and substance as well as the scholastic curriculum. With the exception of a few conspicuous concerns in the electrical and chemical industries, our employers have followed the practice of training men for their specific needs rather than as a part of a broad professional education. The author has come to believe that the schools must take a more active and positive hand in the matter. Where the cooperative plan does not seem practicable or desirable—and this will probably remain true of a majority of our institutions—it is now time to consider how a required period of practice, under specifications which cover the character as well as the amount, may be made prerequisite for graduation.

The responsibility of the professional organizations for setting up proper codes of qualifications, to serve as guides to both scientific and practical training, needs constant urging. It is a source of weakness to our technical education that the schools, the professional bodies and the industries are not in clear agreement on the aims to be sought and the specifications to be met. It would be possible, of course, to go to the opposite extreme and fit technical education into a strait-jacket; another possibility, scarcely more attractive, would be to reduce all technical education to a process of training for specific jobs. The present danger in the colleges is all on the other side, that of a vague comprehensiveness, while the practical training in industry is too often subordinated to immediate objectives. Until the colleges have a clearer understanding of the further training which their graduates are to receive from employers, they will be in no position to deal intelligently with the amount and kind of training in engineering applications to be included in the basic college program.

The More Intensive Forms of Higher Education.— Here our record affords the sharpest contrast with that of Europe. It is impossible to claim that our present concentration of effort in degree-granting colleges represents an intelligent handling of the situation. This subject is dealt with in extended form in another report. The author therefore limits the present discussion to the bare statement of his conviction that we should erect a second educational ladder, extending through the post-secondary age levels, more strongly oriented to the higher practical pursuits of industry, intended primarily for those who have been or are collaterally engaged in active industrial pursuits, and suited to the vast number of promising young men who are not primarily book-minded but lend themselves better to more direct, practical and inductive methods of learning, such as one often finds exemplified in industry. These schools should, for the most part, give briefer and more practical programs than the colleges, base their admissions on direct evidence of ability and interest and only incidentally on formal scholastic credentials, and base their instruction as far as practicable on direct analyses of vocational usage. Suitable credentials for these educational programs, possibly similar to the National Diplomas and Certificates in Great Britain, should be developed under national auspices. The programs of these schools may well be of three general types: (1) engineering courses of fairly broad aims which parallel the university courses in more intensive fashion, but with their own distinctive teaching materials and methods; (2) courses in the technology of specific industries, such as textile manufacturing, printing, building construction, foundry practice and the like, which probably will never be largely covered in the university scheme; and (3) courses of preparation for specific technical functions, such as power plant or building superintendence, quantity surveying, textile designing, and the like. European experience, confirmed by all the available American data, indicates that schools of this character are the normal source of recruitment for many higher posts in the operating as distinct from the planning side of industry. The potential field in America for schools of these types is apparently double, or even treble, that of the professional schools of engineering.

Conclusion.—One who essays to compare forms of education with which he has long been familiar with other national forms which he must approach across barriers of tradition and often of language, under well intentioned but unconsciously biased guides, is under constant danger of setting the worst of his own nation against the best in the schemes of others. It is too much to hope that this difficulty has been fully overcome in the present study. We must not forget that we are training American youth for American life, at an age level where problems of personal adjustment are most acute. These problems are greatly accentuated by the freedom of our social order and bulk far larger in our educational scheme than in any other. Our teachers must guide as well as instruct, our students must experiment with life as well as with mechanisms. Our colleges must supply incentives from within which abroad are largely supplied through economic pressure from without. In short, our technical education will avail little if it is not thoroughly human as well as scientific.

Nor can we forget that America has left behind her an era of economic isolation. We must live increasingly in realms of world competition, where our rivals will strive to their utmost to offset our favorable position with respect to raw materials and rich home markets through the intensity of their scientific efforts. We can and will, as special needs arise, continue to import specially trained technical personnel; we dare not, however, become dependent on any external sources. Part, at least, of our technical education must be lifted to higher scientific levels.

To set before the engineering colleges some uniform, idealized scheme of curriculum and press for its universal adoption would work against progress. The problem of the curriculum is secondary and is preceded by other problems —definition of aim, selection of function, rational choice of educational process, building up an environment of creative activity, supplying incentives for superior achievement, and most of all, developing and maintaining a body of notable teachers.

The immediate need in our technical education is a rational diversification, to advance a limited part of it to definitely higher scientific and professional levels, to provide far more generous training for the higher practical pursuits of industry, and to strike a better balance between dominantly technical and dominantly managerial programs. The crux of the problem is to unite a higher concern for individual development with both a higher intellectual standard and a higher practical standard of technical preparation, ends achieved abroad through selective processes which reach to the very foundations of the social structure. The author is convinced that we will not solve this dilemma through a single, comprehensive type of school, nor by a compromise type of program. Our schools need more clearly visualized aims and programs, and a willingness to accept different but equally worthy functions in the social order.

A well proportioned national system of technical education will not grow up spontaneously. The entire situation needs to be visualized, a consistent but duly flexible policy formulated and an effective guiding and promotional effort sustained. These are joint responsibilities of educators, the organized technical professions and industry. In the absence of any national educational authority, we should strive to build up a joint representative agency of the various groups concerned—schools, colleges, professional societies, industries —and put to the test American capacity for self-government through group cooperation.

THE ENGINEERING GRADUATE IN INDUSTRY

The National Industrial Conference Board Studies of 1924–1925

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The data given in the following tables represent the result of a continuation and more concrete development of the studies in the field of engineering education carried on by the National Industrial Conference Board. Six major industries were selected for investigation. Of these the data applying to four was partially reported upon in a paper in Volume 32 of the *Proceedings,* published in 1925.* For the sake of completeness and with the permission of the editor this report has been revised to cover all six industries which were studied by the Conference Board. The material is presented in as condensed a form as possible, as it is believed that the data contained in the tables is of more particular interest to this report.

It should be recalled that this work was carried on with the guidance and advice of a committee of sixteen eminent industrialists and educators, called the Advisory Joint Conference Committee on Engineering Education. This committee was appointed jointly by the Society for the Promotion of Engineering Education and the National Industrial Conference Board, as explained in the foreword to the paper previously published in the Society *Proceedings.*†

The purpose of the survey was to determine what positions in industry were filled by college trained men and from the study of their experience and that of their employers to determine in what way college training might better qualify graduates for the positions which they are called upon to fill in industry. It was believed that the information collected might permit one to draw deductions regarding what might be necessary to insure a closer and more responsible relationship between engineering education and industry.

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* See also Special Report No. 25, entitled "Engineering Education in American Industry," published by the National Industrial Conference Board. The substance of this report was presented at the Ithaca meeting of the Society for the Promotion of Engineering Education in June, 1923.

† See *Proceedings of the Society for the Promotion of Engineering Education,* Ithaca meeting, 1923, Vol. 31, p. 136.

In the following the term "technical education" refers to all such engineering and scientific education as is usually given in institutions of recognized college grade. In like manner, "technical men" and "technical graduates" refer to those who have had technical training of college grade. Because many men in industry are graduates of other than technical college courses, these have been considered and referred to as "non-technical college men." The term "college," when used alone, includes all colleges, whether technical or not.

The Number of College Men in Industry

These tables present in concise form a part of the primary statistical data provided by the companies which cooperated in the studies. The most important points brought out by these tables are noted below.

Table I gives the number of college men in each industry as determined from the reports received from all the companies cooperating. These figures cover a total of 1,081 establishments with over a half-million employees.

1. Over ten per cent. of the men in these industries today hold executive or other positions of importance,* and of these nearly one fifth are college graduates. (Column 7, fifth, seventh and ninth items.) †

2. It appears that the electrical industry uses the largest proportion of college trained employees and the textile industry the smallest proportion.

Table II shows the distribution of men among the various industries according to their principal training.

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* For list of positions see Table V.

† All men who had spent two or more years in college were considered "college trained." Of these about 81 per cent. had received a degree and 11 per cent. had received two or more degrees.

TABLE I

NUMBER OF COLLEGE MEN IN INDUSTRY

	Industry						
	1	2	3	4	5	6	7
	Paper and Pulp	Rubber	Textiles	Metal Trades	Chemical	Electrical	Total
1. Total employees in industry*	115,430	124,738	738,089	777,310	329,472	161,204	2,246,243
2. Employees in establishments cooperating in this survey	36,113	100,100	147,500	109,261	34,895	153,505	581,374
2*a*. Per cent of total	31.29%	80.3%	20.0%	14.1%	10.6%	95.22%	25.9%
3. Employees in technical and supervisory positions of item 2	2,662	6,920	8,856	16,736	5,511	22,913	63,598
3*a*. Per cent of item 2	7.4%	7.0%	6.1%	15.3%	15.8%	14.9%	10.9%
4. College men with technical training-item 2	472	966	861	1,965	1,305	7,515	13,084
4*a*. Per cent of item 3	17.8%	14.0%	9.7%	12.3%	23.7%	32.8%	20.6%
5. College men, total	576	1,637	†1,210	2,963	1,635	8,494	16,514
6. Per cent of item 3	21.6%	23.6%	13.7%	17.75%	29.7%	37.1%	25.8%

* From U. S. Census of Occupation, 1921

† Number with non-technical training estimated.

TABLE II

EDUCATION OF COLLEGE MEN IN INDUSTRY

Major Subject	Industry													
	Paper and Pulp		Rubber		Textiles*		Metal Trades		Chemical		Electrical		Totals	
	Number of Men Reported	Per cent of Total College Men	Number of Men Reported	Per cent of Total College Men	Number of Men Reported	Per cent of Total College Men	Number of Men Reported	Per cent of Total College Men	Number of Men Reported	Per cent of Total College Men	Number of Men Reported	Per cent of Total College Men	Total Number Men Reported	Total Per cent of College Men
Chemistry or Chemical Engineering	246	42.7%	484	29.5%	236	27.4%	140	4.7%	1,007	61.6%	196	2.3%	2,309	14.3%
Mechanical Engineering	130	22.6%	281	17.2%	124	14.4%	1,573	53.0%	141	8.6%	999	11.8%	3,248	20.1%
Electrical Engineering	36	6.2%	73	4.5%	20	2.3%	249	8.4%	42	2.6%	6,053	71.2%	6,473	40 1%
Civil Engineering	29	5.0%	52	3.2%	19	2.2%	97	3.3%	48	2.9%	58	0.7%	303	1.9%
Textile Engineering	—	—	—	—	437	50.8%	—	—	—	—	—	—	437	2.7%
Mining, Metallurgy or Geology	9	1.6%	—	—	—	—	44	1.5%	29	1.8%	51	0.6%	133	0.8%
Forestry	22	3.8%	—	—	—	—	—	—	—	—	—	—	22	0.1%
Other Engineering	—	—	76	4.6%	25	2.9%	82	2.8%	38	2.3%	160	1.9%	381	2.3%
Non-engineering	104	18.1%	671	41.0%		—*	778	26.3%	330	20.2%	977	11.5%	2,860	17.7%
Totals	576	100.0%	1,637	100.0%	861	100.0%	2,963	100.0%	1,635	100.0%	8,494	100.0%	16,166	100.0%

* Non-engineering college men omitted.

TABLE III

Reasons for Entering the Industry

	Industry					
	Paper and Pulp	Rubber	Textiles	Metal Trades	Chemical	Electrical
Number of Men Reporting	204	325	219	770	185	684
Reason	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Ownership	12.3%	3.1%	13.2%	5.5%	7.0%	1.5%
Father's Trade	4.9	0.6	6.3	2.2	1.6	0.4
Relatives or Friends	4.9	13.7	8.2	11.0	6.5	7.2
The local industry	5.9	2.2	4.6	2.1	1.6	0.8%
Home Connection	28.0%	19.6%	32.3%	20.6%	16.7%	9.9%
Previous business connection	8.9%	2.2%	5.5%	4.7	1.1%	0.7%
Summer employment	4.9	1.5	0.9	2.7	0.6	1.7
Services solicited	5.4	6.2	6.4	7.1	5.4	2.5
Business Experience	19.2%	9.9%	12.8%	14.5%	7.1%	4.9%
Definite personal choice	25.1	52.3	32.9	40.6	64.3	74.0%
Advice of school	2.0	7.1	6.4	3.4	3.2	4.0
Answered Advertisement	1.5	0.9	0.5	2.5	2.2	1.7
Conscious Selection	28.6%	60.3%	39.8%	46.5%	69.7%	79.7%
No Definite Influence	24.3%	10.2%	15.1%	18.2%	6.5%	5.5%

TABLE IV

Analysis of Positions Held by College Men in Six Industries*

Group of Positions	Men in Group			College Men in Group			Technically Trained College Men in Group			College Men in Group with Other than Engineering Training		
	1	2	3	4	5	6	7	8	9	10	11	12
	Number	Per Cent of Total All Groups (Col. 1)	Per Cent of Total Employees †	Number	Per Cent of Group (Col. 1)	Per Cent of Total College Men (Col. 4)	Number	Per Cent of Group (Col. 1)	Per Cent of Total Technical Men (Col. 7)	Number	Per Cent of Total Group (Col. 1)	Per Cent of Total Non-technical Men (Col. 10)
General Officers	3,771	5.9	0.65	1,723	45.7	10.7	1,117	29.6	8.4	606	16.1	21.8
Technical	10,796	17.0	1.86	5,189	48.1	32.2	5,013	46.5	37.6	176	1.61	6.3
Production	20,939	32.9	3.61	1,694	8.1	10.5	1,459	7.0	10.9	235	1.1	8.4
Sales	14,902	23.4	2.56	5,703	38.3	35.4	4,523	30.3	33.9	1,180	7.9	42.4
Miscellaneous	13,185	20.8	2.26	1,806	13.7	11.2	1,221	8.9	9.2	585	4.4	21.1
Total	63,598	100.0	10.94	16,115	25.4	100.0	13,333	20.9	100.0	2,782	4.4	100.0

* Paper and Pulp, Rubber, Textiles, Metal Trades, Chemical and Electrical Manufacturing industries.

† See Table I. Total employees of reporting companies equals 581, 374.

TABLE V

NUMBER AND TRAINING OF MEN IN TECHNICAL AND SUPERVISORY POSITIONS IN SIX * INDUSTRIES

Position	Total No. of Men	The Number Below Had their Principal Education in																
		Chemistry or Chemical Engineering		Mech. Eng.		Electrical Engineering		Civil Eng.		Mining or Metallurgical Engineering		Other Engineering		Other than Engineering Subjects		No Special Subjects	Totals	
		N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	N	C
President	597	29	65	30	66	15	34	2	10	—	6	17	19	35	117	152	280	317
Vice President	653	21	58	25	83	11	46	1	8	2	5	15	29	48	121	180	303	350
Secretary	477	11	27	13	29	8	11	—	4	—	1	16	10	59	128	160	267	210
Treasurer	426	17	39	13	19	9	7	1	7	—	—	14	24	51	105	120	225	201
Other General and Assistant Officers	795	18	28	7	48	24	47	1	10	—	2	13	24	97	225	251	411	384
Managers	823	31	118	63	116	19	65	4	13	2	8	19	31	63	66	205	406	417
TOTAL GENERAL OFFICERS	3,771	127	335	151	361	86	210	9	52	4	22	94	137	353	762	1,068	1,892	1,879
Chief Engineer	405	8	12	60	136	22	69	2	21	1	3	10	4	4	3	50	157	248
Other Engineers	3,277	23	73	344	575	343	1,316	7	46	1	12	81	49	32	71	304	1,135	2,142
Draftsmen	4,553	15	9	1,350	841	489	177	16	33	—	2	64	63	119	58	1,317	3,370	1,183
Laboratory	2,124	259	995	21	57	41	255	1	6	9	31	7	52	51	44	295	684	1,440
Development Dept.	437	7	66	81	79	—	13	1	5	—	2	2	11	31	32	107	229	208
TOTAL ENGINEERING AND TECHNICAL	10,796	312	1,155	1,856	1,688	895	1,930	27	111	11	50	164	179	237	208	2,073	5,575	5,221

General Superintendent	627	35	64	68	53	10	10	1	5	—	3	58	44	21	31	224	417	210
Other Superintendents	1,180	67	151	97	59	30	27	3	9	2	5	54	38	76	39	523	852	328
General Foreman	1,598	49	95	107	18	29	12	2	1	2	—	32	5	134	63	1,049	1,404	194
Other Foremen	12,554	625	68	404	55	112	60	2	3	—	4	464	191	534	201	9,831	11,972	582
Master Mechanic, Erection and Field Men	2,010	9	3	307	156	18	142	1	24	1	1	132	22	40	10	1,144	1,652	358
Inspector	2,970	3	10	160	50	76	64	—	3	1	3	2	1	125	13	2,459	2,826	144
TOTAL PRODUCTION	20,939	788	391	1,143	391	275	315	9	45	6	16	742	301	930	357	15,230	19,123	1,816
Sales Manager	772	60	37	24	46	8	44	8	5	2	2	16	21	43	108	356	509	263
Asst. and Dist. Sales Managers	1,786	53	40	32	109	93	315	3	13	1	3	18	6	263	199	638	1,101	685
Salesmen	8,540	44	137	79	176	760	1,762	9	35	5	21	80	52	1,408	616	3,356	5,741	2,799
Sales Engineer	1,485	4	15	109	174	63	874	1	17	—	6	4	6	55	53	104	340	1,145
Export	404	3	2	2	8	14	172	—	—	—	—	—	—	125	32	46	190	214
Advertising	714	—	14	4	26	7	176	—	7	1	2	—	4	58	164	251	321	393
Other Sales Positions	1,201	1	7	4	37	59	143	1	5	—	—	2	4	49	49	840	956	245
TOTAL SALES	14,902	165	252	254	576	1,004	3,486	14	82	9	34	120	93	2,001	1,221	5,591	9,158	5,744
Purchasing	1,068	16	18	33	26	17	15	—	4	2	3	10	11	174	84	655	907	161
Traffic	1,462	10	3	9	5	8	2	—	2	—	—	6	2	215	76	1,124	1,372	90
Employment and Industrial Relations	485	5	19	3	12	4	12	—	2	1	—	3	11	74	102	237	327	158
Accounting and Financial	3,165	9	11	14	14	15	23	1	2	—	3	42	27	404	297	2,303	2,788	377
Miscellaneous	7,010	145	125	329	180	69	516	1	20	—	5	241	89	486	199	4,545	5,816	1,194
TOTAL MISCELLANEOUS	13,190	185	176	388	237	113	628	2	30	3	11	302	140	1,353	758	8,864	11,210	1,980
GRAND TOTAL	63,598	1,577	2,309	3,792	3,253	2,373	6.469	61	320	33	133	1,422	850	4,874	3,306	32,826	46,958	16,640

* Paper and Pulp. Rubber, Textiles, Metal Trades, Chemical and Electrical Manufacturing industries.

Note: In the N column are listed the men who have had training in the subject, but THIS TRAINING WAS NOT ACQUIRED IN COLLEGE. In the C column are listed all those who have had college training.

It is natural that an industry should employ those men whose major training best fits them for its needs. The figures showing the type of training received by the college men who entered these industries supports this fact.

Table III gives an approximate analysis of the reasons given by college trained men for entering the industry where now employed.

The question was asked ''How did you happen to enter the industry in which you are now employed?'' The analysis of the replies is probably not without some overlapping. For example, a ''definite personal choice'' may have been influenced by ''home connection.'' The electrical industry appears to have shown the more definite attraction for college trained men and the paper and pulp and textile industries the least.

Table IV shows the type of position, or class of work, in which college trained men are engaged in industry.

In general it appears that the higher the positions the larger is the proportion of college trained men who occupy them. The proportion of college trained men in the production positions is notably low. The sales departments use a large proportion of college men; over thirty per cent. in this classification were technically trained while only about eight per cent. had general college training, other than engineering or technical. However, most of the men with non-technical college training are in the sales group. Those with technical college training distribute between the technical and sales classifications with the former receiving slightly the larger share.

Table V gives the detailed distribution of the men occupying the more important supervisory and technical positions in industry. The non-college men who had received some training in the various subjects indicated are listed in the columns headed ''N.'' The college trained men are all in the columns headed ''C.'' Often men trained in law, medicine, general academic or other subjects are found in industrial positions. These are all grouped together under the heading ''Other than engineering subjects.''

The occupations claiming the larger number of the college men employed in industry are in the order of importance: Sales, Engineering, Laboratory Work, and Drafting.

Tables VI and VII are included to show what subjects college men in industry have found of importance and which were perhaps not sufficiently covered in their college studies.

TABLE VI

SUBJECTS STUDIED BY COLLEGE TRAINED MEN SINCE LEAVING COLLEGE

As indicated by men employed in six industries—Pulp and Paper, Rubber, Textiles, Metal Trades, Chemical and Electrical Industries

(Figures show number of men mentioning each subject)

Non-Engineering Subjects	
Reading	597
Business Administration	420
Salesmanship	115
Industrial Management	62
Economics	75
Accounting	67
Law	56
Correspondence School and I.C.S.	50
Mathematics	44
English	29
Public Speaking	18
Physics	18
Psychology	16
Cost Accounting	12
Languages	12
Finance	8
Research	7
Literature	4
History	3
Typography	2
Advertising	2
General	2
Styles	1
Biology	1

Engineering and Technical Subjects	
General Engineering	120
Chemistry and Chemical Engineering	114
Electrical Engineering	102
Mechanical Engineering	87
Pulp and Paper Making	29
Textiles	25
Metallurgy	19
Production and Production Methods	14
Civil Engineering	13
Rubber	11
Industrial Medicine	6
Metallography	2
Time Study	2
Purchasing	2
Agriculture	2
Dyes	2
Forestry	1
Cotton Growing	1
Manufacturing Processes	1
Traffic	1
Ceramics	1
Geology	1

TABLE VII

SUBJECTS IN WHICH COLLEGE TRAINED MEN IN INDUSTRY WOULD HAVE LIKED MORE INSTRUCTION IN COLLEGE

As indicated by men employed in six industries—Pulp and Paper, Rubber, Textiles, Metal Trades, Chemical and Electrical Industries

(Figures show number of men mentioning each subject)

Engineering and Technical Subjects		*Non-Engineering Subjects*	
Chemistry	240	Business Administration	456
General Engineering	181	Economics	226
Mechanical Engineering	130	Accounting	179
Electrical Engineering	115	Public Speaking	139
Industrial Management	104	Law	138
Metallurgy and Metallography	50	Psychology	122
Production and Production Methods	33	Salesmanship and Advertising	118
		English	101
Paper Making Course	32	Finance	83
Textiles and Textile Engineering	25	Mathematics	71
		General Science and Physics	66
Civil Engineering	14	Liberal Arts	55
Rubber	12	Languages	52
Forestry	10	Sociology	10
Chemical Engineering	10	Ethics and Philosophy	6
Industrial Medicine	9	History	4
Printing	5	Stenography and Shorthand	3
Hydraulics	3	Miscellaneous	2
Geology	2		
Ceramics	2		
Photography	2		
Time Study	1		

ADAPTATION OF COLLEGE MEN

The data given in the tables was obtained from two sources: first, from official representatives of the management of each establishment; second, from the college trained men in these establishments. Data from the management was obtained from over one third of the establishments canvassed. Data on the college men came from about twenty-five per cent. of those canvassed.

The information thus collected permits of certain deductions as follows:

1. These industries as a whole offer very little in the way of further systematic training for the college men which they absorb. Only thirty-one companies report having any form of systematic training for college men after their employment. Nevertheless over a thousand men reported that they had done some kind of studying since entering industry, although over 89 per cent. proceeded with their studying on an entirely independent basis. The largest number of men depended upon the reading of trade journals and technical books to keep themselves abreast of developments in their lines (see Table VI); others followed correspondence courses or other systematic study of business administration, accounting, or the special technology of their industry.

2. A large proportion of college men feel the lack of experience or of some specific knowledge or ability is the greatest impediment to their advancement rather than faulty college training. Individual personal limitations and industrial conditions, such as slack business, or unprogressive company policies are other difficulties frequently mentioned.

3. Summer employment for college students is considered highly desirable and valuable by the majority of college men reporting.

4. As a general rule the college men who followed after graduation the lines of their college training are satisfied with their technical and engineering courses, though some definitely indicated the lack of one or more particular courses which they believe would have been helpful in their industry, and all have done further studying.

5. The majority of the companies use college men with technical training, which indicates that there is a very definite place for such men in their industry. The textile industry seems to be an exception as in its case the majority of the companies do not make extensive use of engineering graduates.

6. Only a small number of companies use college men dur-

ing summer vacation periods, and even fewer have had any experience at all with college instructors in summer employment.

7. Thirty-one of the companies participate in cooperative education whereby students are used in alternate periods of practical work and college study.

8. Nine of the companies have established fellowships at technical colleges. Fifty-one companies refer research work to college laboratories.

9. The companies reporting seem to have no standard practice for recruiting the services of technically trained men. In some cases, application is made direct to the colleges, but in the larger number of cases it is left to chance acquaintances or application on the part of the men. The larger companies, whose representatives appear at the engineering colleges in the spring of the year in large numbers, are really the exception when all manufacturing establishments are considered.

10. Thirty-five companies send representatives to the colleges to give lectures on various aspects of industry.

11. Sixty-two companies have had good results in using technically trained men in positions which previously were filled by men without technical training. A considerable number of companies report good experience in using college men with other than technical training in positions of a more or less technical nature. Of the companies replying as to the importance or personality to the success of a college man in industry, the great majority feel that it is of primary importance. Some consider this of minor importance in strictly technical positions.

Suggestions by College Graduates

Constructive criticisms were solicited from the college men and the executives who cooperated in the study. The college men emphasized the following points:

1. College men should, in addition to cultural and technical training, have some training in general business subjects.

2. More technical men should be used on production

methods, ways of reducing waste, standardization, and research.

3. Provide for the college men employed an opportunity to secure a perspective of the entire industry so that they may better correlate their specific activities with a knowledge of the entire process.

4. There is need of a definite and fair promotion plan based on merit and accomplishment.

5. There is need for closer cooperation between technical colleges and industry to the end that the student may be better fitted for his future work.

6. It is advisable for young men to work during summer vacations in industry so that they may choose more intelligently the particular branch of the industry in which they wish to specialize.

Suggestions by Management

The management group offer the following suggestions:

1. Bring the colleges and industries closer together so that each may have a clearer and more comprehensive understanding of the problems of the other.

2. Train college men in the fundamentals and train them in thinking, leaving the highly specialized knowledge to be attained after the men enter the industry. This makes for greater flexibility in the ultimate use of college men.

3. The colleges might well send out their instructors during summer vacation periods to work in industrial plants, thus affording an opportunity for those who teach to keep closely in touch with the current practice of industry. Visits and conferences between plant executives and college department heads were also suggested by several.

4. Encourage summer employment in industry for college students.

Conclusions

It appeared evident that such faults as might be found with the engineering graduate's training, either by employers or by the men themselves, was a much broader matter than concerned the engineering colleges alone. Certainly secondary schools might do much to improve the education and adaptation of young men to their chosen fields of efforts. The educational system, as a whole, is in need of study and readjustment to the conditions of our time.

Many men undoubtedly choose the wrong careers. Young men go to college who are ill-prepared and often poorly adapted to education of scholastic type. Opinions supporting these conclusions were expressed frequently by industrial employers and employees who lacked college training as well as by those who were engineering college graduates. At least no difference of opinion on this subject could be traced to the educational experience of the men who expressed themselves.

The main points which should receive the attention of both those in the commanding positions in industry and in the educational field appear to be:

1. What can industry do
    - (*a*) to aid the vocational guidance of young men so that those best adapted for an industry may select it.
    - (*b*) to shorten the time in which college graduates may become fitted for responsible positions which will challenge the effective use of their training?
2. What can colleges do
    - (*a*) to develop the personality of their graduates;
    - (*b*) to give their graduates such a command of the English language as to enable them to express their ideas clearly and convincingly.
    - (*c*) to enable graduates to choose more wisely vocations which are adaptable to their personality and training?

The educational problem should be attacked by industrialists and educators in cooperation to obtain results which will bring greater efficiency to both industry and the educational system with resulting benefit to society as a whole.

PRELIMINARY REPORT OF THE COMMITTEE ON ECONOMICS

This Committee was appointed at a meeting of the Board of Investigation and Coordination held early in November, 1925, the first notification being in a letter to the members bearing date Nov. 10, 1925.

Early in December the Chairman and Secretary met Mr. Hammond in Chicago and spent a day in the discussion of the work of the Committee and of the form of questionnaires best adapted to draw out the information which would be necessary as a basis for sound conclusions.

After correspondence with members of the Committee the final revision of the questionnaire was completed in February and on March 9th the printed blanks were ready to be mailed.

Two sets of questions were sent out:

1. The questionnaire to colleges, asking for specific information as to the extent, character and purpose of the course in economics for engineering students offered by each, and information as to the rank and experience of the men teaching economics.
2. The questionnaire to engineers in practice, designed to draw out suggestions based on personal experience.

Owing to the fact that less than three months has been available for the mailing of questionnaires, the preparation of the replies, and the analysis and tabulation of the information, the Chairman of your Committee did not secure material upon which to base this report until June 3d. This is of necessity therefore, a mere presentation of information, and in no sense a report which has been participated in by the members of the Committee.

I. Data Supplied by the Colleges of Engineering

Responses to the questionnaire have been submitted by 111 institutions.

1. *Economics as a Requirement*

	Number	Per Cent
Colleges which require courses in Economics as part of the curriculum for students of Engineering	91	82.0
Colleges which do not require such courses	20	18.0

The titles of the required courses reported indicate a wide range of subject matter covering the entire field of business administration, finance and accounting.

Eighty-one of the Colleges (72.9 per cent) report Economics, Political Economy or ''Engineering Economy'' as the title, thus indicating courses in the theory of economics, 7 (6.3 per cent), report Business Law, while the balance of the schools reporting give titles which indicate that banking, finance, accounting and various business and industrial administration courses are given. 19 colleges (17.1 per cent of the total) make no statement.

In connection with the requirements of the different curricula the following figures are of interest.

		Per Cent
Civil Engineering	76	68.4
Electrical Engineering	72	64.8
Mechanical Engineering	68	61.2
Chemical Engineering	45	40.5
E. M. & Met. E.	33	29.7
Architectural Engineering	11	9.9
Others	48	43.2

2. *Total hours* for all courses in Economics in connection with Engineering Curricula.

		Per Cent
0 to 25	19	17.1
25 to 50	27	24.3
50 to 75	38	34.2
75 to 100	15	13.5
100 to 150	44	39.6
Over 150	4	3.6

Three Colleges give this work in the freshman year, 25 in the sophomore, 53 in the junior and 45 in the senior year.

3. *Department in which courses are given.*

		Per Cent
Economics	45	40.5
Arts & Science	17	15.3
Pol. Econ. & Social Science	12	10.8
Commerce	7	6.3
Engineering	7	6.3
Business Administration	5	4.5
English	1	.9

This tabulation indicates that the placing of the teaching of Economics under the administration of engineering schools has not met with general favor.

4. The third question, what is the major purpose of the course, general broad training in economic theory, or the giving of specific economic problems, brought out the following answers:

		Per Cent
Economic Theory	73	65.7
Specific Economic Problems	2	1.8
Both	15	13.5
Half and Half	3	2.7
Unstated 2, Unclassified 1		

5. The following is the information secured as to those who teach Economics to engineers:

		Per Cent
Professors	73	65.7
Associate Professors	21	18.9
Assistant Professors	45	40.5
Instructors	30	27.0
Graduate Assistants	6	5.4
Practicing Engineers	1	.9
Chartered Accountants	1	.9

The answers to this question indicate that in general the teaching of this work is in the hands of mature and experienced men the large majority of whom hold graduate degrees.

Seventy-eight Colleges report that specific economic problems are introduced in the teaching of engineering subjects, while 17 do not do so, and 16 do not report or are unclassified.

In 84 colleges emphasis is placed on the economic aspects of engineering, in 13 it is not and 14 either do not state or are unclassified. This is variously done by lectures in 8, by discussion in 12, by special emphasis in 27 and by problem work in 32.

Without attempting to present further abstracts of the voluminous figures derived from the questionnaire to the colleges, we may sum up by stating that there is abundant evidence that the importance of economics in the engineering curriculum is recognized by a majority of the institutions reporting; there is a notable tendency to permit considerable freedom of elections in economic and business subjects; and these things are equally true in all the major fields of engineering specialization.

II. Data Supplied by Engineers in Practice

1. *The Men Who Responded*

Questionnaires were mailed to 276 individuals, and replies were received from 127. Of these 115 were graduates, 3 were not college men and 9 were not classified.

Eleven men held degrees from two institutions, and 46 different colleges are represented in the replies.

Forty held Civil Engineering degrees, 34 Electrical, and 27 Mechanical, 8 held the degree of B.S., 3 degrees from Arts Colleges, while Chemical, Mining, Metallurgical and Marine Engineers were each represented. The large majority have been out of college from ten to forty years, only ten per cent having graduated prior to 1885 and five per cent since 1815. Ten per cent of the replies did not state the year of graduation.

The connection of these men is as follows:

		Per Cent
Manufacturing	38	29
Public Utilities	37	28
Consulting Engineers	33	26
Municipal Engineers	5	4
Teaching, less than 1 per cent		
Unstated	13	10

Their positions are:

		Per Cent
Proprietor	5	4
President or Vice-President	15	12
Chief Engineer	20	16
Manager or Superintendent	28	22
Engineer	50	39
Professor or Dean	1	less than 1
Unstated	8	7

This résumé of information as to the men who replied leads the committee to believe that these responses represent a very fair cross-section of the field of engineering, and that they ought to give a very good reflection of professional opinion as it now prevails.

2. *Economic Problems in the Field of Engineering*

The answers to questions 1*a* and 1*b* appear to present these matters so fully, and the answers to question 2 indicate such unanimity of opinion that they are here given.

1*a*. Please name the class or classes of problems in your field of effort in which questions arise of General economics (Political Economy) meaning the matter generally given under this head in college departments of Economics or Political Economy.

	Per Cent
Valuations, Price Tendencies, Labor Problems	15–12
Cost of Public Utility Services, Rates, etc.	11– 9
Transportation Eng.	9– 7
Legislation, Taxation	8– 6
Manufacturing	4– 3
Water Power & Wks., Rates for	3– 2
Salaries—Personnel	3– 2
Business Law	3– 2
City Planning—Mun. Eng.	2– 1
Traffic Estimates, Finance	1–
Wealth & Its Distribution	1–
Corporation Finance	1–
Teaching Economics	1–
General	11– 9
Unstated	42–32
None	12–10

1*b*. Please name the class or classes of problems in your field in which questions arise of Practical Economics (sometimes called Engineering Economics) as, for example, the determination of the more economical method of procedure when there is more than one method; the setting of costs of operation against fixed charges; cost analysis; public utility problems, financing of industry; marketing; personnel problems; etc.

	Per Cent
Cost Analysis, Fixed Charges	46–36
Operation of Railroads	12–10
All Problems mentioned in the question	9– 7
Manufacturing	8– 6
Designs, Bridges, etc.	7– 5
Reports, Appraisals, Rates	6– 4
Transportation—Tonnage—Speed	4– 3
City Planning	4– 3
Telephone Engineering	3– 2
Water Supply—Sewage Disposal—Drainage	3– 2
Industrial Plant Operation	2– 1
Valuations, Financing	1–
Personnel Problems	1–
Business Administration	1–
Unstated	10– 9
General	9– 7
None	1–

2. Does your experience indicate the desirability of including in college engineering courses:

	Per Cent
a. General Economics (Political Economy)	
Yes	98–77
No	9– 7
Unstated	20–16
b. Practical Economics	
Yes	111–87
No	6– 4
Unstated	10– 9

3. *Recommended Methods of Teaching Economics*

It appears from the foregoing that while there is practical agreement on the need of such courses, the answers to Question three and four show decided differences of opinion.

“3. Remembering the many absolutely necessary items in an engineering curriculum, should these courses, if you regard either or both as desirable, be given thorough study or merely outlined with illustrative examples, but with emphasis on their importance?

	Per Cent
a. General Political Economy	
Outlined	67–53
Thorough	31–24
Unstated	29–23
b. Practical Economics	
Thorough	55–43
Outlined	52–40
Unstated	20–17

“4. Should Political Economy or Practical Economics be taught as independent courses or in conjunction with the study of engineering problems to which they apply?

	Per Cent
a. Political Economy	
Independent	61–48
Eng. Prob.	41–32
Unstated	25–20
b. Practical Economics	
Eng. Prob.	92–72
Independent	15–12
Unstated	20–16”

Many well considered opinions were expressed in response to question 7. Ten of the replies substantially agree on the Case method of Teaching, and approximate the following:

> “By working out actual problems or cases relating to engineering which illustrate the application of principles taught. The fundamentals of economics and habits of thought and analysis should be much expanded in engineering curricula, and teachers should have had experience to give point to their statements.”

Five others express themselves in essence as follows:

> “Subjects classed as 1*b* come vitally into the engineer’s work after he has been practicing long enough to leave strictly routine work, and should be given careful attention along with engineering subjects. I consider political economy one of the most important, if not the most important study in one’s education, and I believe every engineering course should include an intensive course in practical economics. In introducing the study of Economics the relation to applied engineering and possible future responsibility to be

> placed on graduate engineers should be stressed. It has been my observation that most engineering students are narrow in their ability to attack the broader phases of engineering problems. While concrete suggestions to overcome this are difficult the teaching of general economics and the stressing of practical economics in dealing with class problems can but be helpful.''

Many of the other answers to this question are such as to justify their inclusion in this report.

4. *Comparison of Engineering and Business Graduates*

While 67 say that they have had occasion to observe the graduates of both classes of schools, and 44 have not, the answers to the second part of the question show loyalty to the engineering school.

As to which are better able to handle the economic element of the problems of industry, the following is the expression:

Graduates Engineering	54
Graduates Business Courses	14
Graduates Liberal Arts	11
Unstated	55

The concluding paragraph of a most carefully prepared three-page answer to one of the questions states the view of the writer as follows:

> ''The above may seem a somewhat lengthy answer to a short question, but I have been so impressed with the almost complete ignorance of engineering graduates on all questions of engineering economics that I felt the subject entitled to some elaboration. In fact, I doubt if the framers of the question understand just exactly what they are trying to bring out.''

CONCLUSION

The foregoing greatly abridged presentation of the information drawn from the Questionnaires is all that can be submitted in the extremely limited time available.

To those who have had to do with the financing, building, operation and management of great engineering works of all kinds, it is obvious that the economic problems are of such importance that the man who cannot solve them will always remain a ''hewer of wood and a drawer of water.''

To those who have been many years in teaching it is equally obvious that the college cannot expect or hope to put in the curriculum all of the subjects that the graduate may or will use in his career after leaving college.

It becomes a question then of determination as to what are *fundamental subjects,* and of excluding those things that are not now essential in order that room may be found for those which have become so.

Recently the Dean of one of the large schools of Business Administration defined Engineering as "applied economics." Whether one agrees with the definition or not, one cannot avoid the conclusion that a knowledge of economic theory, accounting and statistical analysis are absolutely essential in modern business, and that if the engineer is to be a leader in modern business he must possess this knowledge.

It would seem to be perfectly obvious that the curriculum in engineering which does not include these courses is deficient.

Discussion is challenged on a number of questions. How shall these courses best be taught? By the department of Economics in the Arts or Business Schools? By teachers of Economics in the Engineering School? Or in large part by the introduction of problems in Economics in professional courses in Engineering?

Shall we frankly recognize the tremendous changes which have been taking place in industry in the last twenty-five years, and the place which the engineer occupies in industry, and make our basic training such as is required to fit men for business rather than for scientific research or for technical engineering work, leaving to the Graduate School such specialized training?

These and many other questions are involved, and before expressing its own final conclusions your committee invites full discussion.

For the Committee:

HENRY E. RIGGS,
Chairman.

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